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EFFECTS OF A SHOULDER HARNESS ON LITTER CARRIAGE  
PERFORMANCE AND POST-CARRY FATIGUE OF MEN AND WOMEN

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**EFFECTS OF A SHOULDER HARNESS ON LITTER CARRIAGE  
PERFORMANCE AND POST-CARRY FATIGUE OF MEN AND WOMEN**

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| 13. ABSTRACT (Maximum 200 words)<br>The purpose of this study was to determine whether an ergonomically designed harness would improve soldier performance during and after litter carrying. Two litter carrying tasks were used: 1) a simulated mass casualty task; carrying and loading as many patients as possible within 15 mins and 2) a simulated removal from a remote site, carrying the litter at a constant rate of 4.8 km/hr for as long as possible, up to 30 min. Each task used a repeated measures design to determine differences in harness use, team size, and gender. Soldiers (12 men and 11 women) were measured on the following measures: rifle marksmanship, a fine motor task, heart rate and oxygen uptake while litter carrying, time of carry, number of carries, and ratings of perceived exertion. During the mass casualty task, men carried and loaded more patients than women (18 vs. 14 carries), and women reported greater soreness/discomfort than men post-carry. Using a harness resulted in faster fine-motor performance (47.6 vs. 46.1 sec) and lower subjective ratings of physical symptoms than with a hand carry. Carrying in 4-person rather than 2-person teams increased the number of carries completed by 0.5 carries and improved fine-motor performance by 1.6 sec. Women's marksmanship scores improved when carrying in 4-person teams. The 2-person hand-carries were perceived as requiring the greatest exertion and resulted in greater soreness/discomfort and light-headedness post-carry. For the removal of casualties from a remote area, men carried the litters 75% longer than women. When using a harness, soldiers carried patients longer (23 min vs. 6 min), had slightly lower heart rates, and worked at a higher percent of VO2max (46 vs. 42%). Harness use resulted in more fatigue in the shoulder, neck, and chest and less fatigue in the forearm and hand. The 2-person, hand carry teams carried the litter for 4.2 min (men) and 1.8 min (women), while 4-person, hand carry teams carried the litter for 13.9 min (men) and 4.7 min (women). The 4-person teams were able to maintain pre-carry fine-motor and marksmanship scores. Working in 4-person teams allowed for longer litter carries while working at a lower percent of VO2max (43 vs. 45%). |   |  |                            |  |  |
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## TABLE OF CONTENTS

|  |      |
|--|------|
| LIST OF FIGURES .....                                | vi   |
| LIST OF TABLES .....                                 | viii |
| ACKNOWLEDGMENTS .....                                | ix   |
| EXECUTIVE SUMMARY .....                              | 1    |
| INTRODUCTION .....                                   | 3    |
| BACKGROUND ON LITTER CARRYING .....                  | 4    |
| EFFECT OF TASK-INDUCED FATIGUE ON MARKSMANSHIP ..... | 5    |
| PSYCHOLOGICAL EFFECTS OF FATIGUING EXERCISE .....    | 5    |
| METHODS .....  | 6    |
| VOLUNTEERS .....                                     | 6    |
| HARNESS DESIGN AND DEVELOPMENT .....                 | 6    |
| 2-Person Carry .....                                 | 9    |
| 4-Person Carry .....                                 | 10   |
| TRAINING .....                                       | 10   |
| PROFILING MEASUREMENTS .....                         | 10   |
| Aerobic Power .....                                  | 11   |
| Muscular Strength .....                              | 11   |
| Physical Fitness Test .....                          | 12   |
| Body Composition .....                               | 12   |
| PHYSIOLOGICAL AND PERFORMANCE CHARACTERISTICS .....  | 13   |
| DESIGN .....   | 13   |
| GENERAL PROCEDURE .....                              | 14   |
| INDEPENDENT VARIABLES .....                          | 14   |
| Carry Type .....                                     | 14   |
| Team Size .....                                      | 16   |

|  |    |
|--|----|
| Harness Use .....                                | 16 |
| Dependent Measures .....                         | 18 |
| Treadmill Data .....                             | 18 |
| Fine-motor Coordination .....                    | 18 |
| Marksmanship .....                               | 19 |
| Heart Rate .....                                 | 19 |
| Energy Cost .....                                | 20 |
| Litter Motion .....                              | 20 |
| Perceived Exertion .....                         | 20 |
| Soreness, Pain, and Discomfort (SPD) .....       | 21 |
| Profile of Mood States (POMS) .....              | 21 |
| Environmental Symptoms Questionnaire (ESQ) ..... | 21 |
| STATISTICAL ANALYSIS .....                       | 21 |
| RESULTS: REPEATED CARRY .....                    | 21 |
| TREADMILL DATA .....                             | 23 |
| FINE-MOTOR COORDINATION .....                    | 24 |
| MARKSMANSHIP .....                               | 24 |
| LITTER MOTION .....                              | 32 |
| HEART RATE .....                                 | 34 |
| PERCEIVED EXERTION .....                         | 34 |
| SORENESS, PAIN, AND DISCOMFORT (SPD) .....       | 35 |
| PROFILE OF MOOD STATES (POMS) .....              | 37 |
| ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE (ESQ) ..... | 37 |
| DISCUSSION: REPEATED CARRY .....                 | 39 |
| GENERAL EXERCISE .....                           | 39 |
| GENDER .....                                     | 40 |
| HARNESS .....                                    | 40 |
| TEAM SIZE .....                                  | 41 |
| TEAM SIZE X HARNESS .....                        | 43 |
| CONCLUSIONS: REPEATED CARRY .....                | 43 |

|  |    |
|--|----|
| RESULTS: CONTINUOUS CARRY .....                  | 45 |
| TIME OF CARRY .....                              | 45 |
| FINE-MOTOR COORDINATION .....                    | 46 |
| MARKSMANSHIP .....                               | 48 |
| LITTER MOTION .....                              | 50 |
| HEART RATE AND OXYGEN UPTAKE .....               | 51 |
| PERCEIVED EXERTION .....                         | 53 |
| SORENESS, PAIN, AND DISCOMFORT (SPD) .....       | 53 |
| PROFILE OF MOOD STATES (POMS) .....              | 53 |
| ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE (ESQ) ..... | 53 |
| DISCUSSION: CONTINUOUS CARRY .....               | 56 |
| GENERAL EXERCISE .....                           | 56 |
| GENDER .....                                     | 56 |
| HARNESS .....                                    | 57 |
| TEAM SIZE .....                                  | 58 |
| CONCLUSIONS: CONTINUOUS CARRY .....              | 60 |
| REFERENCES .....                                 | 61 |
| APPENDIX A .....                                 | 64 |
| APPENDIX B .....                                 | 65 |

## LIST OF FIGURES

|   |    |
|---|----|
| Figure 1. Strap and harness designs to aid litter carrying .....  | 8  |
| Figure 2. Litter carry test-station, positioned over a motor driven<br>treadmill (4-person carry) .....                                 | 15 |
| Figure 3. Harness for 2-person carry .....  | 17 |
| Figure 4. Harness for 4-person carry .....  | 17 |
| Figure 5. Number of carry cycles completed, harness x team size<br>interaction .....  | 23 |
| Figure 6. Cord and cylinder task: main effects for gender,<br>team size, and harness .....  | 30 |
| Figure 7. Marksmanship: distance from center of mass (DCM)<br>for accuracy, speed and accuracy, and sighting<br>time main effects ..... | 30 |
| Figure 8. Marksmanship: distance from center of mass (DCM) for<br>speed and accuracy for gender x team size interaction .....           | 31 |
| Figure 9. Marksmanship: shot group tightness (SGT) for speed and<br>accuracy for gender x harness x team size interaction .....         | 32 |
| Figure 10. Post-exercise marksmanship: shot group tightness (SGT)<br>for gender x harness x team size .....                             | 33 |
| Figure 11. Litter movement: main effects for gender and team size .....   | 33 |
| Figure 12. Ratings of perceived exertion: harness x team size interaction .....   | 34 |
| Figure 13. Profile of Mood States (POMS): main effects for pre/post<br>ratings of depression and fatigue .....                          | 37 |
| Figure 14. Carry time: main effects for gender, team size and harness<br>condition .....  | 46 |
| Figure 15. Carry time: gender x team size interaction .....   | 47 |
| Figure 16. Cord and cylinder task: main effects for gender and<br>pre-/post- carry differences .....                                    | 47 |
| Figure 17. Cord and cylinder task: harness x pre-/post- carry interaction .....   | 48 |
| Figure 18. Marksmanship: shot group tightness (SGT) when shooting<br>for accuracy only, gender x harness interaction .....              | 49 |



|  |    |
|--|----|
| Figure 19. Marksmanship: shot group tightness (SGT), when shooting<br>for speed and accuracy, gender x team size x pre-/post-<br>carry interaction ..... | 49 |
| Figure 20. Litter movement: gender x team size interaction .....   | 50 |
| Figure 21. Litter movement: harness x team size interaction .....  | 51 |
| Figure 22. Exercise intensity: main effects for gender, team size and<br>harness .....   | 52 |
| Figure 23. Exercise intensity: gender x harness interaction .....  | 52 |

## LIST OF TABLES

|  |    |
|--|----|
| Table 1. Subjective harness ratings .....  | 9  |
| Table 2. Physical characteristics of men and women .....   | 13 |
| Table 3. Number of carries completed in 15 min .....   | 22 |
| Table 4. Differences between gender, team size, and harness condition for the<br>four different phases of the 15-min repeated litter-carry (sec) ..... | 25 |
| Table 5. Carry type by gender effects for the four different phases of the<br>15-min repeated litter-carry (sec) .....                                 | 26 |
| Table 6. Team size by carry type effects for the four different phases of the<br>15-min repeated litter-carry (sec) .....                              | 27 |
| Table 7. Team size by carry type by gender effects for the four different<br>phases of the 15-min repeated litter-carry (sec) .....                    | 28 |
| Table 8. Team size by gender effects for the four different phases of the<br>15-min repeated litter-carry (sec) .....                                  | 29 |
| Table 9. Soreness, Pain, and Discomfort (SPD): main effects<br>(anterior/posterior, p value) .....   | 36 |
| Table 10. Environmental Symptom Questionnaire (ESQ): main effects<br>(p value) .....   | 38 |
| Table 11. Continuous carry times (min) for men and women .....   | 45 |
| Table 12. Soreness, Pain, and Discomfort (SPD): post-carry main effects<br>(anterior/posterior, p value) .....   | 54 |
| Table 13. Environmental Symptoms Questionnaire (ESQ): subjective<br>ratings main effects (p value) .....   | 55 |

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## EXECUTIVE SUMMARY

The purpose of this study was to determine whether an ergonomically designed harness would improve soldier performance during and immediately following litter-carrying. Two litter-carrying tasks were used: (1) a simulated mass-casualty task; carrying and loading as many patients as possible within 15 min and, (2) a simulated removal from a remote site, carrying the litter at a constant rate of 4.8 km/hr for as long as possible, up to 30 min. Each task used a repeated measures design focused on harness use (harness-carry, hand-carry), team size (2-person, 4-person) and gender (men, women). Soldiers (12 men and 11 women) fired at targets, completed a fine-motor coordination test, and filled out three questionnaires before and after both litter-carrying tasks. Time of carry, and number of carries, as well as a continual assessment of heart rate, oxygen uptake, and perceived exertion were measured for the litter-carrying exercises. Analysis of variance (ANOVA) and post hoc Newman-Keuls Comparison of Means were used to examine the data.

During the mass-casualty task, gender, team size, and harness use affected the ability of soldiers to transport, defend, and medically treat patients. Men carried and loaded more patients compared with women (18 vs. 14 carries), and women reported greater soreness/discomfort than men post-carry. Using a harness resulted in faster fine-motor performance (47.6 vs. 46.1 sec) and lower subjective ratings of physical symptoms than with a hand-carry. Carrying in 4-person rather than 2-person teams increased the number of carries completed by 0.5 carries, improved fine-motor performance by 1.6 sec, and reduced subjective reports of physical symptoms. Womens' marksmanship scores improved when carrying in 4-person teams. The 2-person hand-carries were perceived as requiring the greatest exertion and resulted in greater soreness/discomfort and light-headedness post-carry. For a mass-casualty scenario, tactical planning should deploy sufficient numbers of soldiers for 4-person, litter-carrying teams. A harness system should be available for exigencies requiring 2-person teams and for female teams.

For the task of removal of casualties from a remote area (continuous task) gender, team size, and harness use also affected soldiers' abilities to transport and medically treat patients, and their ability to maintain pre-carry marksmanship scores. Men carried the litters 75% longer than women. When using a harness, soldiers carried patients longer (23 min vs. 6 min), had slightly lower heart rates, and worked at a higher percentage of  $VO_2\text{max}$  (46 vs. 42%  $VO_2\text{max}$ ). Harness use resulted in more fatigue in the shoulder, neck, and chest, and less fatigue in the forearm and hand. The 2-person, hand-carry teams carried the litter for  $4.2 \pm 1.8$  min (men) and  $1.8 \pm 1.0$  min (women), while 4-person, hand-carry teams carried the litter for  $13.9 \pm 6.9$  min (men) and  $4.7 \pm 1.2$  min (women). The 4-person teams were able to maintain pre-carry fine-motor and marksmanship scores. Working in 4-person teams allowed for longer litter-carries while working at a lower percentage of  $VO_2\text{max}$  (43 vs. 45%). It is suggested that the policy of using 4-person teams be enforced, and that harness systems be included with the supply of litters for any situation that requires 4-person litter-carrying for greater than 5 continuous min or 2-person litter-carrying for greater than 2 continuous min.

This work has resulted in a number of publications. A list of the publications may be found in Appendix A.

## INTRODUCTION

A less restrictive ground combat assignment policy has been initiated that will increase assignment opportunities for women. However, the capacity of female soldiers to perform physically demanding tasks remains in question (24), as research efforts regarding women's performance have not been commensurate with the increase of women in nontraditional occupations (5). Most performance and equipment standards are based on the average test volunteer (young, white, male undergraduate) or the average soldier (young, male) and do not address the ability of women to adequately perform physically demanding work (23). Inadequate matching of personnel capabilities and task assignments results in increased costs in the form of supplemental training, inadequate performance, and work-related injuries. Three methods of controlling these costs are performance prediction modeling, task-specific-training, and ergonomic design. This research addressed ergonomic equipment design for the occupational task of litter-carrying.

Women have difficulty with heavy lifting and carrying tasks that require substantial upper body strength, such as carrying tool boxes and litters (24,25). Reduced manpower or space limitations may require that litter-carrying be a 2-person rather than a 4-person task. While these difficulties affect litter-carrying performance, soldiers often identify field expedient methods of accomplishing difficult operations. For example, soldiers sometimes hook the litter grips over their web belt to enable completion of the Expert Field Medical Badge (EFMB) litter-course (personal communication with SFC P. Cespedes, 5 June 1990), presumably to rest their hand and arm muscles.

The purpose of this study was to examine whether use of an ergonomically designed harness would affect litter-carrying performance, and post-carry weapon firing and fine-motor performance. Additional goals were to determine if the effects of harness use would be more pronounced depending on team size and gender of litter-bearers. Given that mood state affects physical performance, we also examined whether a shoulder harness and team size would alter mood state during litter-carrying. The research was conducted in three phases: harness design and

development, laboratory efficacy testing, and field usability testing (reported elsewhere (26)).

## **BACKGROUND ON LITTER-CARRYING**

In one of two studies of litter-carrying found in the literature, Lind and McNicol (16) determined that a patient of average build produces a load on each litter handle of approximately 20 kg and examined the cardiovascular responses of men. The men held 40 kg (20 kg in each hand) for 2.5 min, and 40 kg (with a shoulder harness) for 15 min. Holding 20 kg in each hand quickly induced fatigue, while holding the same amount of weight with a shoulder harness was accomplished easily and without a fatiguing response. The weight held was varied to determine the load that induced fatigue. For the non-harness condition, the weight which induced fatigue was between 10 and 15 kg. With a shoulder harness, 80 kg was supported without fatigue for 15 min. When asked to hold the litter handles and carry a patient weighing 82 kg on a litter at 2 miles per hour on level ground, participants stopped after an average of 3 min due to fatigue. Subjects were not fatigued after 15 min of carrying a patient when a shoulder harness was used. Lind and McNicol (16) used all right-handed male subjects to perform a 2-person litter-carry. No attempt was made to identify factors associated with successful litter-carry performance, nor was an acceptable level of performance identified. The energy cost of the litter-carry was not measured; therefore, the efficiency of the shoulder harness could not be quantified. Lind and McNicol (16) measured fatigue by subjective response and inability to continue the task. No women were included in the study, nor were 4-person teams (required by Army doctrine) considered.

The Canadian Air Force conducted a study to determine the relationship between standard, annually administered physical fitness tests and litter-carrying performance (1). The physical tests included grip strength, push-ups, sit-ups, and a submaximal aerobic fitness test. The litter-carrying task was self-paced, and required subjects to carry an 80-kg load a distance of 500 m without running. A technician carried the foot end of the litter for each subject whose heart rate was monitored. Results revealed limited predictive capability for females and none for

males. The lack of significant predictors for men was likely due to the fact that the task was submaximal.

## **EFFECT OF TASK-INDUCED FATIGUE ON MARKSMANSHIP**

Firing a rifle accurately is an important skill for combat. It is also important to recognize that soldiers may be required to defend both themselves and their patient after the near maximum physical effort of carrying litter patients to evacuation ambulances.

Although the effects of litter-carrying on marksmanship have not been previously quantified, past research has shown the extent to which physical and physiological changes can affect rifle shooting accuracy. In one study, shooting accuracy of soldiers was impaired after the completion of a competitive 20-km road march (13). At 4300 m altitude, shot impact distance from target center increased after strenuous walking and running (31). In both studies, decreased accuracy was explained by an increase in body tremors in response to exercise fatigue and an elevated heart rate (13,31). Following exercise on a cycle ergometer (simulating metabolic intensity of the biathlon cross-country skiing phase), decrements in shooting accuracy were attributed to increased body sway (22). In related research, poorer marksmen showed poorer postural stability (10).

## **PSYCHOLOGICAL EFFECTS OF FATIGUING EXERCISE**

Personal psychological perception has been shown to affect performance in various physical tasks. Furthermore, the psychological profile of the individual contributes greatly to their physical ability to perform to physiological limits (21). Morgan (21) reports that successful athletes possess a different and more desirable psychological profile than do unsuccessful athletes. Assessments of athletes' moods using the Profile of Mood States (POMS) show those who are successful exhibit the iceberg profile consisting of higher vigor and lower negative moods than college norms.



## **METHODS**

### **VOLUNTEERS**

Written informed consent was obtained from each participant following a detailed briefing. (Participants included 12 men and 12 women; however, complete data are only available on 11 women.) The briefing included a review of the study objectives, a description of the protocol and procedures, and information on the right to terminate participation at any time. All volunteers were medically screened prior to participation.

### **HARNESS DESIGN AND DEVELOPMENT**

Harness and task design involved an interactive process between subject matter experts (SMEs) and investigators. Subject matter experts included medical personnel who have used litters during combat or mass-casualty situations, training personnel for the Medical Specialist Course, medical evacuation helicopter pilots, ambulance drivers, course instructors for the Expert Field Medical Badge, and hospital-based nursing educators (who supervise mass-casualty exercises). Both the litter-carriers and the patients were considered during project development.

Design objectives were developed as a result of the discussions between SMEs and investigators. The harness design objectives are as follows:

- Comfort
- Weight dispersion
  - Even dispersion
  - Line of pull adjacent to lateral femur
- Weight placement (close to body)
- Adjustable (one size fits all)
- Ease of adjustment
- Safety
  - Harness strength (no slipping or breaking)

- Harness design (prevent dangerous altering of gait)
- Ease of donning/doffing harness
- Ease of lifting and lowering litter
- Litter handles within grasp range

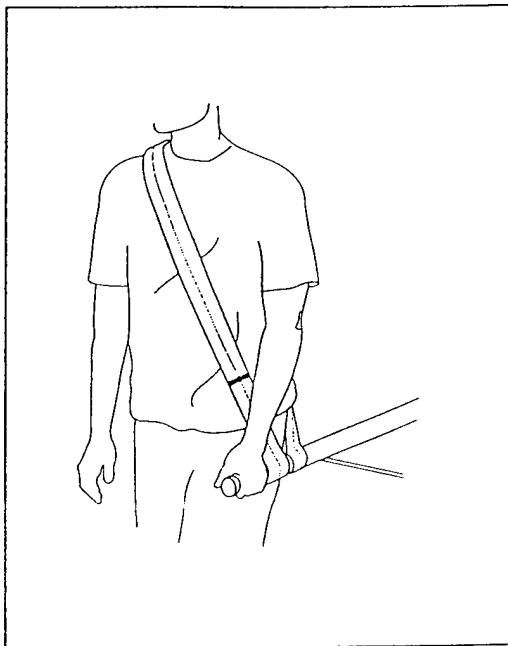
Four harness designs were evaluated for a 2-person carry: 1) a single adjustable strap available in the military procurement system [strap, litter-carrying: 6530 007844 335], 2) military standard load bearing equipment (LBE) as a harness, 3) a belt harness, and 4) an H design harness constructed at USARIEM. These designs are shown in Figure 1. For a 4-person carry, the single-strap system was evaluated in two ways: 1) with both ends of the strap looped over the litter handle and 2) with one strap looped over the litter handle and one strap held in the opposite hand (referred to as "fist"). Holding one strap in the opposite hand is useful in adapting the litter height in difficult terrain.

The procedure was non-experimental, formal, three-dimensional, and performance-oriented. We did not use statistical controls, although we did use contrasting conditions. Five male and five female soldiers volunteered. All volunteers received a detailed briefing, a medical screening, and signed a consent form. Volunteers' demographic data indicated that the sample was representative of the general military population (8,9). A repeated measures design, counter-balanced for order, was used.

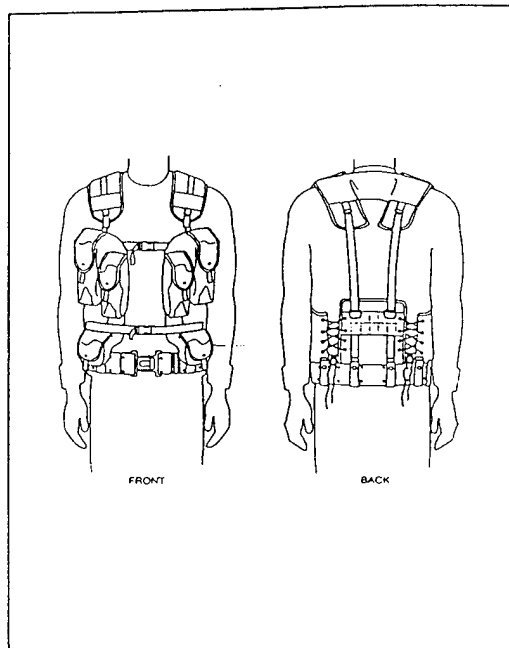
Soldiers carried the head end of a 6.8-kg litter with a 81.8-kg manikin while walking on a treadmill at a self-selected rate of 2.5 - 3.0 mph for 250 meters. Measurements included participant interviews, questionnaires, rankings, and ratings focusing on ease of use, pain/strain, and perceived exertion. Group interviews, rather than open-ended individual interviews, were used to promote discussion and "co-discovery" (18). Investigator observations were also considered.

**Figure 1.** Strap and harness designs to aid litter carrying.

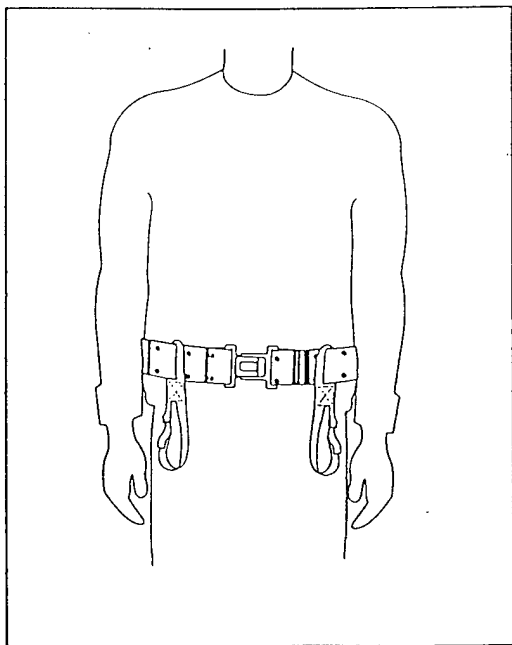
Single Adjustable Strap



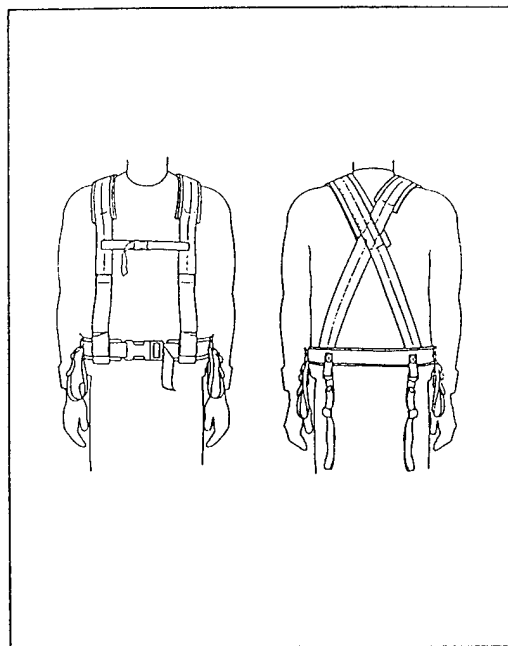
Load Bearing Equipment



Belt Harness



H Design Harness



The Wilcox Matched-Paired Signed Ranks Test for non-parametric statistics was used to evaluate the data with alpha level of 0.05.

## **2-Person Carry**

The belt harness was immediately ruled out due to the amount of horizontal movement transferred from the hip to the litter. Volunteers, especially smaller individuals, had difficulty keeping their balance due to the horizontal swing of the litter. The single strap system (in which two single straps were crossed diagonally across the body) was discarded due to participants' reports of back, neck, and shoulder pain and visible marks on the back of participants' necks. In comparing the LBE and the H-design harness, no significant differences were noted for ease of use, pain/strain, ratings of perceived exertion (RPE), or investigator combined ratings of gait, balance, strap position, participant's posture, and reported strain (Table 1).

**Table 1.** Subjective harness ratings.

| Harness Condition | Ease of Use<br>(lower = better) | Pain/Strain<br>(higher = better) | RPE<br>(lower = better) | Investigator<br>(lower = better) |
|-------------------|---------------------------------|----------------------------------|-------------------------|----------------------------------|
| 2-Person: "H"     | 14.6                            | 20.8                             | 4.3                     | 12.0                             |
| 2-Person: LBE     | 16.9                            | 19.8                             | 4.1                     | 12.3                             |
|                   |                                 |                                  |                         |                                  |
| 4-Person: Loop    | 18.8 <sup>*</sup>               | 21.4 <sup>**</sup>               | 5.3                     | 15.5                             |
| 4-Person: Fist    | 24.7                            | 16.2                             | 5.5                     | 18.3                             |

n = 10

<sup>\*</sup> p < 0.05

<sup>\*\*</sup> p < 0.02

Although the results were not significant, the H-design harness did receive more favorable raw score ratings in all categories except RPE. In addition, two important objectives were not met with the LBE. The straps that attached to the LBE and held the litter handles loosened during carries, thus lowering the position of the litter, and their position was not readily adjustable to correctly align the weight

distribution according to the anthropometric dimensions of the individual soldier. On certain volunteers, the weight distribution was dorsal to the frontal plane, resulting in the participant being pulled backward. Therefore, the H-design harness was selected for the 2-person carry.

#### **4-Person Carry**

Participants found that looping the strap over the litter handles was easier to use ( $p < 0.05$ ) and resulted in less pain/strain ( $p < 0.02$ ) than holding the strap in one hand (Table 1). Looping the strap over the litter handles also received more favorable raw scores on RPE and direct observation by the investigator.

### **TRAINING**

Each participant trained on all eight carrying tasks (2- and 4-person teams, harness and no-harness, 15-min repeated and 30-min continuous carries). Volunteers practiced litter-carrying for approximately 3 weeks. In addition, most volunteers were military medics who had recently completed their Advanced Individual Training including instruction and practice in litter-carrying. Volunteers also practiced a fine-motor coordination (cord and cylinder) task and rifle marksmanship. Volunteers were trained over a three-week period to an asymptotic level (three consecutive test scores were within  $\pm 2.5\%$  of each other).

### **PROFILING MEASUREMENTS**

During the first 2 weeks of the study, profiling measurements were taken and training was conducted. Profiling measures were recorded on all volunteers to include aerobic power, muscle strength (handgrip, 38-cm upright pull, dead lift, bench press, and dynamic lift), Army Physical Fitness Test (APFT) scores, and body composition.

### **Aerobic Power**

Maximal oxygen uptake was determined using a discontinuous, progressive protocol on a motorized treadmill (20). The procedure began with a warm-up at 6 mph (5 mph for women), 0% grade for 6 min, followed by a 5-10 min rest period. Two to four additional runs were performed, each 3-4 min in duration, and interrupted by rest periods. A plateau in oxygen uptake with increasing intensity was the criteria for establishing  $\dot{V}O_{2\max}$ . A plateau is defined as less than a 2-ml increase in oxygen uptake with a 2% increase in grade. Heart rate was monitored with an electrocardiograph recorder.

### **Muscular Strength**

Sustained isometric handgrip of the dominant hand was measured in a seated position according to the American Society of Hand Therapists' recommendation for the standard position for grip strength measurements. The recommendation states that the individual "should be seated, with his shoulder adducted and neutrally rotated, elbow flexed at 90 degrees, and the forearm and wrist in neutral position" (7). Grip strength was assessed as a gradual increase to maximal exertion over 1 to 2 seconds, followed by a sustained maximum voluntary contraction (Caldwell Regimen (3)).

The isometric 38-cm upright pull is a test of lifting strength from a stationary semi-squat position (14). The test requires the participant to assume a semi-squat position while gripping a 38-cm high, round, taped aluminum handle. The handle was attached by a cable to a load cell mounted on a slip-free wooden platform. The maximum pulling force produced was registered on a digital readout. The highest two of three trials within 10% of one another was averaged to obtain upright pulling strength.

One repetition maximum (1RM) strength was measured on the bench press and dead lift. Following a warm-up set, weight was added subsequent to each lift until either 1) the participant elected to stop, 2) the participant could not complete the lift, or 3) the participant could not adhere to the correct lifting posture while

completing the lift. After a failed attempt, weight was removed to yield an intermediate load to assess 1 RM as accurately as possible (to the nearest 1.0 kg). Final weights are generally increased in 4.5 kg increments for men and 2.25 kg increments for women. Adequate rest was provided between each attempt.

Lifting strength was measured on a weight stack machine known as an Incremental Dynamic Lift (IDL). Starting from a bent-knee, straight-back position, volunteers lifted handles attached to the weight stack from a starting position of 30 cm to a height of 152 cm above the floor. Following a warm-up, additional weight plates were added with each attempt, until the participant was unable to complete the lift, elected to stop, or could not adhere to the correct lifting posture while completing the lift.

### **Physical Fitness Test**

All APFT scores were attained within 6 months prior to the study. The APFT includes the number of sit-ups completed in 2 min, the number of push-ups completed in 2 min, and the time to run 2 miles.

### **Body Composition**

Body composition was assessed using anthropometry and hydrostatic weighing. Residual volume was measured in duplicate using the oxygen dilution method (35). If the difference between two trials was greater than 50 ml, a third trial was performed. Residual lung volume was measured sitting in a chair and leaning forward to duplicate the position adopted for hydrostatic weighing. Volunteers performed 10 trials to residual volume underwater (8). All volunteers wore a nose clip to duplicate the residual volume measurement procedure. The two trials that induced the highest values within 20 g of each other were averaged and used in the calculation of density (30). Density was calculated with a correction factor of 100 ml for gastrointestinal gas.

## PHYSIOLOGICAL AND PERFORMANCE CHARACTERISTICS

Physiological characteristics and performance variables of volunteers are presented in Table 2. All male and female values were significantly different from each other ( $p < 0.05$ ), except for number of sit-ups.

**Table 2.** Physical characteristics of men and women.

| Characteristic                                       | Men<br>Mean $\pm$ S.D. | Women<br>Mean $\pm$ S.D. |
|--|------------------------|--------------------------|
| Height (cm)  | 178.4 $\pm$ 7.5        | 162.6 $\pm$ 7.1          |
| Weight (kg)  | 79.2 $\pm$ 13.1        | 58.1 $\pm$ 6.2           |
| Age (yrs)  | 20.8 $\pm$ 2.6         | 23.6 $\pm$ 4.0           |
| % Body Fat   | 15.4 $\pm$ 4.0         | 24.9 $\pm$ 6.5           |
| VO <sub>2</sub> max ( $\ell \cdot \text{min}^{-1}$ ) | 4.2 $\pm$ 0.4          | 2.4 $\pm$ 0.4            |
| Bench Press Max (kg)                                 | 85.8 $\pm$ 19.5        | 38.8 $\pm$ 6.4           |
| Dead Lift Max (kg)                                   | 135.1 $\pm$ 23.2       | 82.1 $\pm$ 11.5          |
| Incremental Dynamic Lift [IDL] (kg)                  | 76.1 $\pm$ 13.0        | 43.2 $\pm$ 8.8           |
| Isometric 38 cm Upright Pull (kg)                    | 119.7 $\pm$ 28.3       | 79.2 $\pm$ 22.2          |
| Hand Grip (kg)                                       | 51.3 $\pm$ 9.4         | 35.3 $\pm$ 9.6           |
| Push-ups (number)                                    | 57.5 $\pm$ 13.0        | 45.8 $\pm$ 11.3          |
| Sit-ups (number)                                     | 64.0 $\pm$ 8.5         | 65.9 $\pm$ 11.7          |
| Two-mile run (min)                                   | 13.7 $\pm$ 1.5         | 16.6 $\pm$ 1.7           |

## DESIGN

A repeated measures design was used, which focused on carry (2- and 4-person) and harness (harness-carry, hand-carry). The order of treatments was counter-balanced; however, all 15-min carries preceded continuous carries.



## GENERAL PROCEDURE

Volunteers walked on a treadmill and carried a military litter holding a manikin to simulate carrying a patient. Immediately before and after carrying, volunteers fired a disabled M-16 rifle equipped with a laser marksmanship simulator system (Noptel ST-1000; Noptel, Oulu, Finland) and completed a fine-motor coordination test (cord and cylinder manipulation). Volunteers carried the litter with and without a harness, in 2- and 4-person single gender teams and in two different types of carries: a 15-min bout of repeated, rapid, short, litter-carries and a continuous carry up to 30 min. Each participant completed eight different carries to assess all possible combinations of the above three litter-carrying parameters. Volunteers had a minimum of 48 hours rest between the different carries.

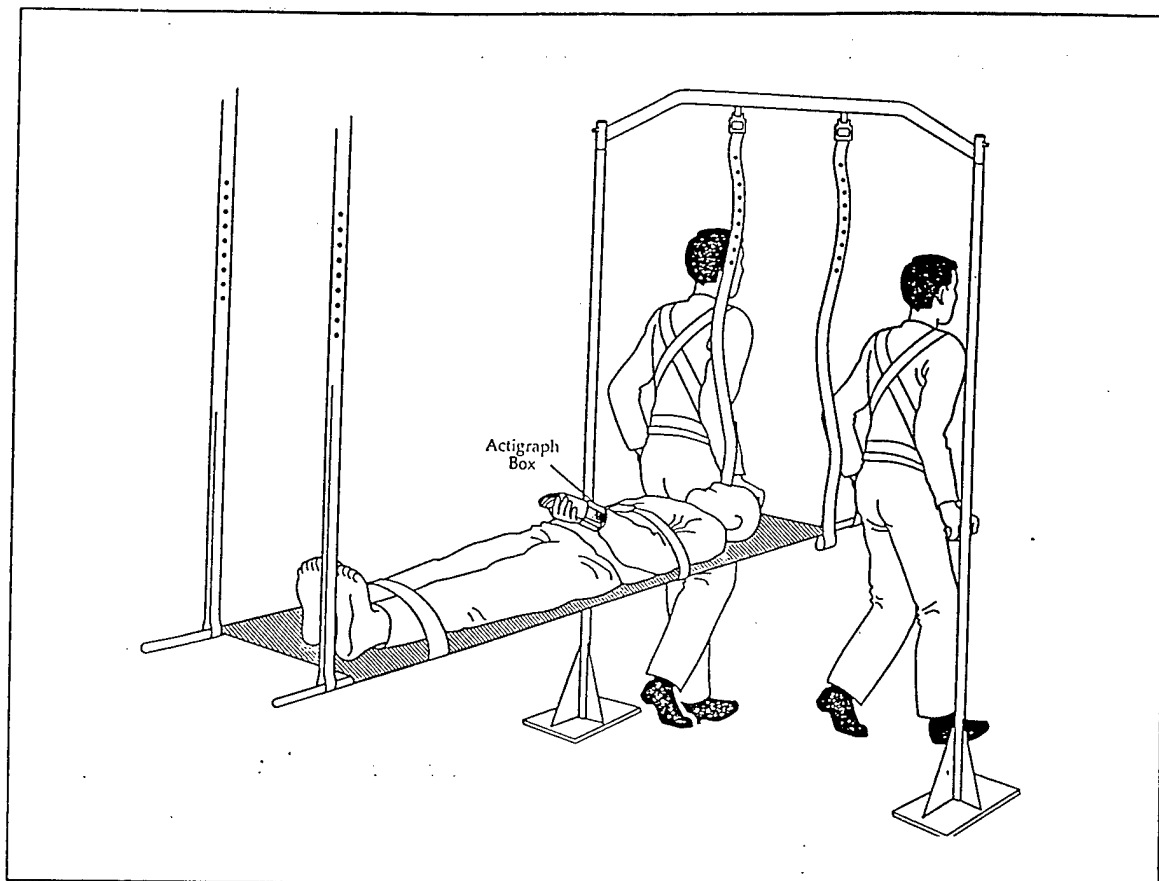
## INDEPENDENT VARIABLES

### Carry Type

After interviewing combat medics, it was decided to evaluate two litter-carrying scenarios: 1) a simulated mass-casualty requiring the carrying of one patient after another for a short distance, from an emergency scene to a waiting ambulance, and 2) carrying a single patient a longer distance from a remote site to a waiting ambulance.

The front-end of the litter, where the manikin's head was located was carried by the volunteer. The foot-end was suspended from an overhead frame by a strap system, which allowed for ease of exit from and entry onto the treadmill, and increased stability of the foot end during the carries (Figure 2). This system allowed for an accurate simulation in terms of weight distribution. However, it was not biomechanically correct, as medics carrying the foot-end would have height and gait differences that would impact on the carrying performances of those at the front end of the litter. For the purpose of this study, it was deemed more important to standardize this variable to assess the impact of harness and team size.

**Figure 2.** Litter-carry test-station, positioned over a motor driven treadmill (4-person carry).



The first carry task simulated carrying and loading as many patients as possible into an ambulance in 15 min. Volunteers carried the litter loaded with an 81.6-kg manikin (similar to the  $78.5 \pm 11.0$  kg weight of the 50th percentile male U.S. Army soldier) 50 m on a treadmill (9). Since the head end of the litter weighs more, the effective weight carried in the front was 45 kg. To enact the physical workload required to load a litter into an ambulance, volunteers dismounted the treadmill and walked/ran 5 m to a weight stack machine, where they lifted a weight equal to the patient load, to a height of 135 cm. The height selected was based on measurements taken of the loading platforms of ground ambulances (M997 and M1010) and air ambulances (Huey and Black Hawk). It is the average of the height required for the ground ambulances and the middle height required for multiple loading in the Huey. Finally, volunteers got back on the treadmill and ran 50 m to simulate retrieval of the next patient. Treadmill speed was self-paced using a toggle

switch attached to the litter handle. Volunteers used the switch to alert a treadmill operator to alter treadmill speed as indicated. Treadmill speeds ranged from 4.8 to 11.3 km/hr while carrying the litter and 4.8 to 20.9 km/hr without the litter (i.e., running to retrieve the next patient). Volunteers were able to put the litter down and rest as necessary.

The second task, the continuous carry, simulated carrying a litter as long as possible without rest breaks for a maximum of 30 min. Treadmill speed was set at 4.8 km/hr. Volunteers were permitted to wear weight-lifting gloves in both types of carries.

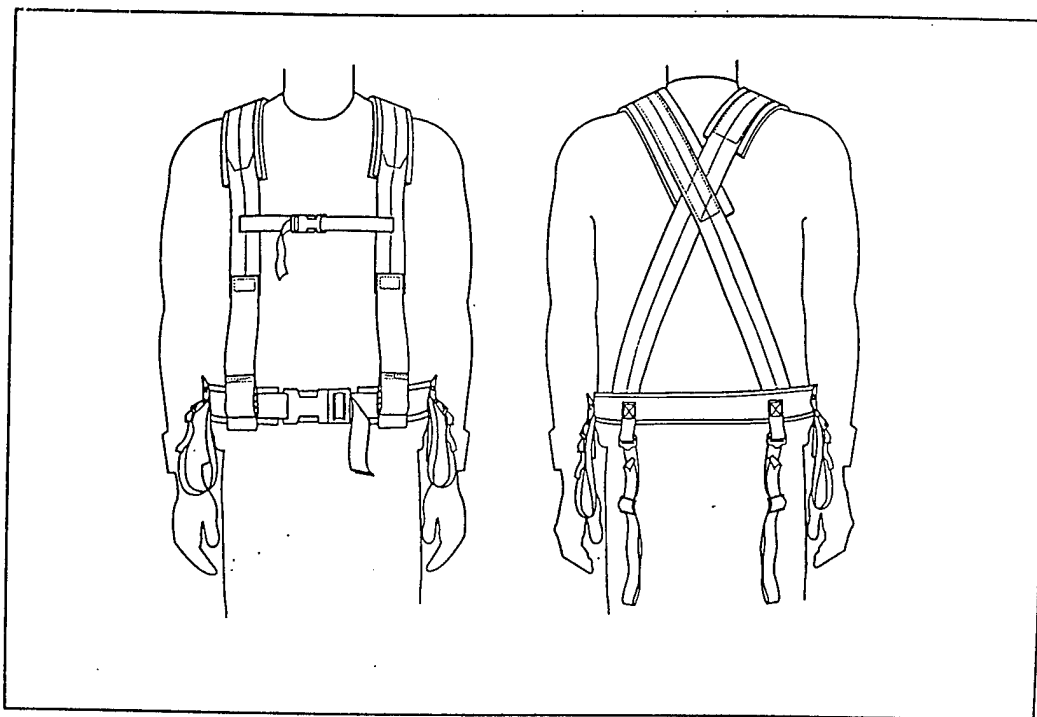
### **Team Size**

Typically 4-person teams are designated to carry litters. However, 2-person teams may be expected to carry litters in some instances (e.g., when sufficient manpower is unavailable). During simulated 2-person carries, one participant supported the front of the litter by holding both head end litter handles (22.5 kg in each hand). For simulated 4-person carries, the front was supported by two volunteers, each holding one of the head end handles (22.5 kg in one hand). Those closest in height were paired together for the 4-person carry to minimize biomechanical difficulties. For each simulated 2-person team, the litter-bearer simulated lifting the litter into an ambulance by lifting slightly more than half the manikin's weight (45 kg) on the weight-stack machine. For each simulated 4-person team, the two litter-bearers simultaneously lifted 45 kg on the machine. Teams were composed of all males or all females. There were no combined gender teams.

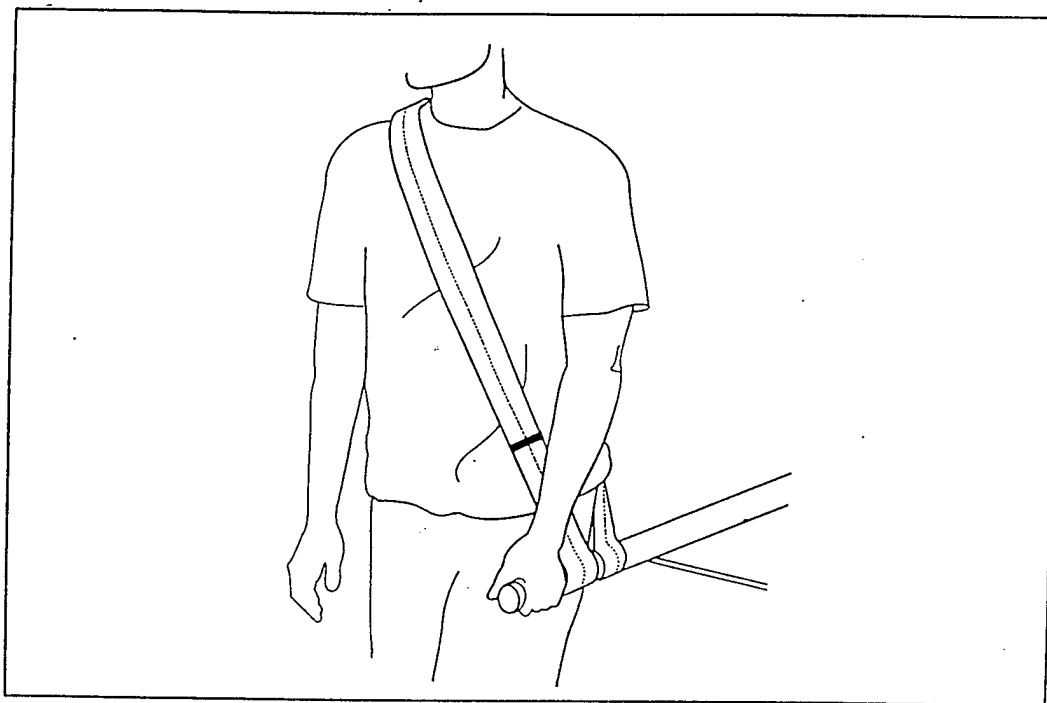
### **Harness Use**

Volunteers carried the litter both with and without a harness. The harness was designed to shift support of the carried weight from the smaller and relatively weaker musculature of the hands to the larger, stronger back and shoulder muscles. The harness in Figure 3 was used for 2-person teams and the harness in Figure 4 was used for 4-person teams.

**Figure 3.** Harness for 2-person carry.



**Figure 4.** Harness for 4-person carry.



## **DEPENDENT MEASURES**

For the repeated carry task, performance measures included number of carry cycles completed, number of lifts completed, and time for each segment of carry cycle (carry, lift, return for next patient, don harness and pick up the litter). During the continuous carry task, performance measures included oxygen uptake and total time volunteers carried the litter. Dependent measures gathered during or immediately before and after both the repeated and continuous carries were fine-motor coordination (time to complete cord & cylinder task), weapon firing (accuracy, and speed and accuracy combined), heart rate, litter movement (patient comfort), ratings of perceived exertion, pain and discomfort scale ratings, Profile of Mood States (POMS), and the Environmental Symptoms Questionnaire (ESQ).

### **Treadmill Data**

Each carry cycle was divided into four sections each representing 25% of the cycle. The four sections were: (1) carry the patient 50 m, (2) dismount the treadmill and lift, (3) remount the treadmill and run 50 m to retrieve the next patient, and (4) pick up the litter. For both the carry and return sections, the number of meters completed was calculated providing a fractional computation. For example, if a soldier completed 14 complete cycles, plus a carry (0.25), lift (0.25), and 10 m of a run (0.20), then their score was 14.7. Each lift was divided into three sections; each section represented 33.33% of the lift. The three sections were lifts to (1) knuckle height, (2) waist height, and (3) full height (135 cm).

### **Fine-motor Coordination**

The cord and cylinder manipulation task is a bi-lateral fine-motor dexterity task that requires volunteers to thread a series of eleven loops of 0.24-cm nylon cord through 10 cylinders. The time required to complete the task is the participant's score (12).

## **Marksmanship**

Marksmanship was quantified with a laser marksmanship simulator (Noptel ST-1000; Oulu, Finland) attached to a de-militarized M-16 rifle. Each marksmanship test consisted of a total of 20 shots. Volunteers shot from a free-standing unsupported position at a 2.3-cm diameter circular target 5 m away. This simulated a 46-cm diameter target at 100 m, which is similar to the standard 49-cm wide, 100 m military human silhouette target. Volunteers were instructed to shoot at will for the first ten shots to obtain the best accuracy score possible. For the second ten shots, instructions were to "shoot as quickly as possible without sacrificing accuracy." During the latter assessment, a verbal ready signal was given. Following a randomly varied 1 to 10 second delay, a red light positioned 8 cm to the left of the target signaled volunteers to begin shooting.

The following marksmanship parameters were calculated:

Distance from center of mass (DCM) = distance (mm) from the center of impact of the shot group to the center of the target (i.e., taking the average [X,Y] coordinate of the shot group and calculating the distance from [0,0] the target center).

Shot group tightness (SGT) = area (mm<sup>2</sup>) of the shot group (i.e., the maximum horizontal distance [X axis] multiplied by the maximum vertical distance [Y axis] between shots).

Sighting time = time in seconds from the illumination of the red light to trigger pull.

Each participant fired two sets of five shots for accuracy and two sets of five shots for speed and accuracy (a total of 20 shots) for each experimental condition. The two sets of measurements for accuracy-only, were calculated and then averaged. The same was done for the speed and accuracy test.

## **Heart Rate**

Heart rate was recorded in 1-min increments throughout both litter-carry tasks using the UNIQ<sub>tm</sub> heartwatch system (Polar Electro, Kempele, Finland). The

system consists of an electrode strap and transmitter that volunteers wore on their chests, and a receiver that resembled a watch that volunteers wore on their wrists.

### **Energy Cost**

Oxygen uptake was measured periodically throughout the continuous litter-carry task. Participants breathed through a low resistance, two-way, non-rebreathing Hans-Rudolf valve, and expired gases were directed into an on-line gas analysis system. Expired gas samples were collected continuously and averaged over 30 sec intervals. Relative exercise intensity, expressed as percentage of maximal  $O_2$  uptake ( $\%VO_{2max}$ ), was calculated by dividing each participant's exercising  $O_2$  uptake by their maximal  $O_2$  uptake expressed relative to body weight ( $ml \cdot kg^{-1} \cdot min^{-1}$ ).

### **Litter Motion**

Litter motion was measured to assess patient comfort with an activity monitor (Ambulatory Monitoring Inc., Ardsley, NY), which was attached to the manikin's wrist. The monitor weighs 3 oz and was the approximate size of a wrist watch (2.5" x 3.5" x .75"). The unit consists of a two-element piezoelectric crystal, sensitive to 0.01 g of force in three planes of motion. When the litter was moved in any direction above this sensitivity, a "count" was registered by the activity monitor. The accelerometric signal was recorded in 60 sec intervals (passband = 0.25-2.0 Hz, sampling rate = 10 Hz). A vertical threshold of 0.25 Hz was used. The mean of the entire testing period, per min, was used for analysis.

### **Perceived Exertion**

Volunteers were asked to rate their exertion level immediately following each carry using a 15-point Likert-type scale, based on the Borg RPE Scale (2).

### **Soreness, Pain, and Discomfort (SPD)**

The pain and discomfort questionnaire required volunteers to rate their level of soreness, pain, and discomfort (SPD) pre- and post-litter-carry on 22 body sections using a modified Corlett and Bishop scale (4) (Appendix B).

### **Profile of Mood States (POMS)**

The POMS (19) questionnaire was used to identify subjective mood changes. The POMS was administered immediately after every marksmanship assessment both pre- and post-litter-carry. The POMS is a 65-item adjective rating scale designed to assess six mood states (tension, depression, anger, vigor, fatigue, and confusion). Each adjective is scored from 0 ("not at all") to 4 ("extremely").

### **Environmental Symptoms Questionnaire (ESQ)**

The ESQ uses a 6-point scale (0, "not at all" to 5, "extreme") from which the soldier rates the intensity of 68 symptoms (27). The ESQ includes symptoms such as fatigue, muscle discomfort, back ache, sweatiness, cardiopulmonary discomfort, thirst, headache, and nausea and was administered pre- and post-litter-carry.

## **STATISTICAL ANALYSIS**

Data were analyzed separately for the two tasks (15-min mass casualty and a carry from a remote site). An alpha level of  $p < 0.05$  was used to indicate statistical significance. A repeated measures analysis of variance (ANOVA) focusing on harness and team size was used. Newman-Kuels post hoc multiple comparisons were used to examine significant results. Only significant results are reported.

## **RESULTS: REPEATED CARRY**

The number of carries completed by men and women in 2- and 4-person

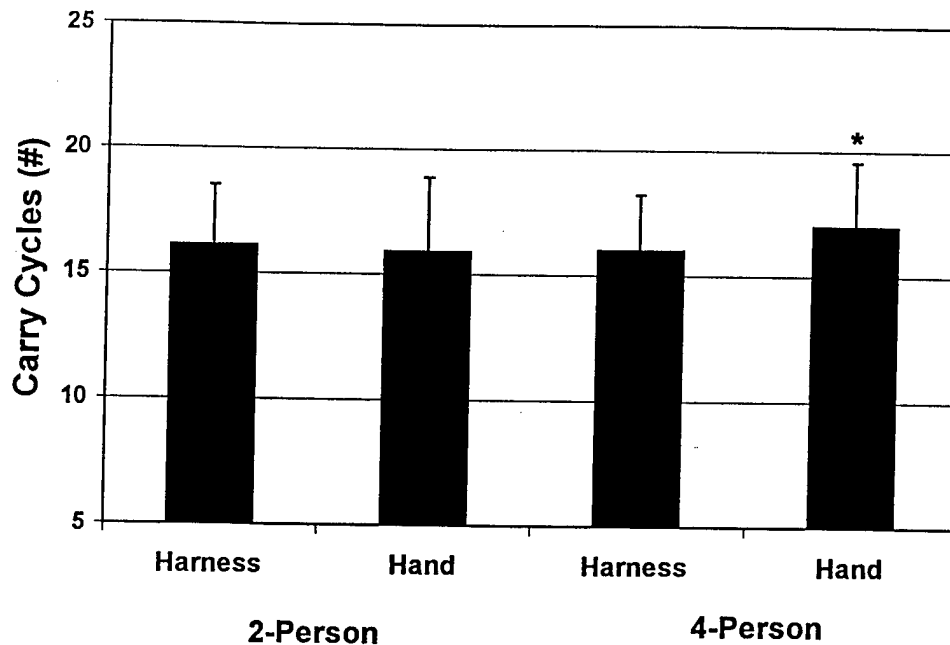


teams can be seen in Table 3. Men completed more carries and lifts than women ( $18.0 \pm 1.6$  vs.  $14.2 \pm 2.0$ ;  $p < 0.0001$ ). A harness x gender interaction ( $p = 0.04$ ) showed that while women completed fewer carries than men in both harness- and hand-carry conditions, women slightly increased the number of carries while using a harness (14.6 carries) compared to without a harness (14.4 carries), while men decreased by a whole carry when using a harness compared to a hand-carry (18.6 vs. 17.6 carries). The post hoc analysis on the team size x harness interaction ( $p = 0.01$ ) showed that 4-person, hand-carry teams completed more carries than any other team size x harness combination ( $p < 0.01$ , Figure 5).

**Table 3.** Number of carries completed in 15 min.

| Carry Type             | Men<br>Mean $\pm$ S.D.<br>(Range) | Women<br>Mean $\pm$ S.D.<br>(Range) |
|------------------------|-----------------------------------|-------------------------------------|
| 2-Person Hand-carry    | 18.1 $\pm$ 1.8<br>(16.7-23.3)     | 13.7 $\pm$ 2.1<br>(11.1-18.0)       |
| 2-Person Harness-carry | 17.8 $\pm$ 1.8<br>(15.3-21.7)     | 14.4 $\pm$ 1.7<br>(12.1-17.0)       |
| 4-Person Hand-carry    | 19.0 $\pm$ 1.1<br>(18.0-21.1)     | 15.0 $\pm$ 2.0<br>(12.8-18.7)       |
| 4-Person Harness-carry | 17.3 $\pm$ 1.3<br>(15.8-18.9)     | 14.7 $\pm$ 2.3<br>(12.0-19.9)       |

**Figure 5.** Number of carry cycles completed, harness x team size interaction.



\*Significantly more carries for 4-Person Hand Carries than other conditions ( $p < 0.01$ ).

## TREADMILL DATA

Carry time (time to carry the litter 50 m) was shorter for men than for women ( $p = 0.0001$ ; Table 4) and was also shorter for 4-person teams compared to 2-person teams ( $p = 0.006$ ; Table 4). A harness x gender interaction ( $p = 0.01$ ) showed women's carry times were slower than men's for both hand- and harness-carries. There was no difference in carry time for men based on using a harness- vs. a hand-carry, whereas women had longer carry times when hand-carrying the litter than when using the harness (Table 5). A team size x harness interaction ( $p = 0.001$ ) revealed carry time was slowest during 2-person hand-carries (Table 6). A team size x harness x gender interaction ( $p = 0.007$ ) revealed that female, 2-person hand-carries were the slowest, while male, 4-person hand-carries were the fastest (Table 7).

The time to dismount the treadmill and lift was completed more rapidly by men

than women ( $p = 0.0003$ ; Table 4). A harness x gender interaction ( $p = 0.01$ ) showed the lift was completed the fastest during men's hand-carries and slowest during women's hand- and harness-carries (Table 5).

Run time (time taken to return 50 m for the next patient) was faster for men than for women ( $p < 0.0001$ , Table 4). A team size x gender interaction ( $p = 0.03$ ) revealed that 2- and 4-person, female teams ran slower than male teams, and that 4-person, female teams were faster than 2-person female teams (Table 8). Time to pick up the litter using a harness was slower than picking up the litter with just the hands ( $p = 0.001$ , Table 4).

### **FINE-MOTOR COORDINATION**

Women completed the cord and cylinder task faster than men ( $p < 0.0001$ ; Figure 6). Volunteers completed the cord and cylinder task faster following a carry in a 4- vs. a 2-person team ( $p = 0.02$ ) and after carrying with vs. without a harness ( $p = 0.04$ ; Figure 6).

### **MARKSMANSHIP**

Distance from the Center of Mass was greater after carrying a litter when shooting for accuracy only ( $p < 0.001$ ), and for speed and accuracy ( $p = 0.02$ ; Figure 7). Post-carry sighting time for speed and accuracy was shorter than pre-carry sighting time ( $p = 0.002$ ; Figure 7).

**Table 4.** Differences between gender, team size, and harness condition for the four different phases of the 15-min repeated litter-carry (sec).

|                | n  | Carry        | Dismount & Lift | Return Run  | Don Harness |
|----------------|----|--------------|-----------------|-------------|-------------|
| Men            | 48 | 19.5 ± 2.1*  | 12.6 ± 1.8*     | 16.5 ± 1.3* | 2.5 ± 1.5   |
| Women          | 36 | 24.3 ± 3.6   | 17.3 ± 4.3      | 20.3 ± 2.1  | 2.3 ± 1.1   |
| 2-Person Carry | 42 | 22.6 ± 4.0** | 15.0 ± 4.1      | 18.4 ± 3.0  | 2.6 ± 1.5   |
| 4-Person Carry | 42 | 21.2 ± 3.2   | 14.9 ± 3.6      | 18.3 ± 2.0  | 2.1 ± 1.0   |
| Hand-carry     | 42 | 22.1 ± 4.3   | 14.7 ± 4.1      | 18.4 ± 2.8  | 1.9 ± 1.3** |
| Harness-carry  | 42 | 21.7 ± 2.9   | 15.2 ± 3.6      | 18.3 ± 2.3  | 2.9 ± 1.1   |

\* Men significantly different from women,  $p < 0.001$ .

\*\* 2-person teams significantly different from 4-person teams,  $p = 0.01$ .

\*\*\* Hand-carries significantly different from harness-carries,  $p = 0.001$ .

**Table 5.** Carry type by gender effects for the four different phases of the 15-min repeated litter-carry (sec).

| Gender | Carry Type | Carry                   | Dismount & Lift         | Return Run | Don Harness |
|--------|------------|-------------------------|-------------------------|------------|-------------|
| Men    | Hand       | 19.3 ± 2.1 <sup>a</sup> | 11.9 ± 1.5 <sup>a</sup> | 16.3 ± 1.3 | 1.8 ± 1.5   |
|        | Harness    | 19.8 ± 2.2 <sup>a</sup> | 13.3 ± 1.8 <sup>b</sup> | 16.6 ± 1.2 | 3.2 ± 1.2   |
| Women  | Hand       | 22.6 ± 4.5 <sup>b</sup> | 17.5 ± 4.4 <sup>c</sup> | 20.5 ± 2.4 | 2.0 ± 1.1   |
|        | Harness    | 21.2 ± 2.3 <sup>c</sup> | 17.1 ± 4.3 <sup>c</sup> | 20.1 ± 1.9 | 2.6 ± 1.0   |

By column, means with different letters are significantly different from each other,  $p < 0.01$ .

**Table 6.** Team size by carry type effects for the four different phases of the 15-min repeated litter-carry (sec).

| Team Size | Carry Type | Carry                   | Dismount & Lift          | Return Run | Don Harness |
|-----------|------------|-------------------------|--------------------------|------------|-------------|
| 2-Person  | Hand       | 23.5 ± 5.1 <sup>a</sup> | 15.2 ± 4.7 <sup>a</sup>  | 18.8 ± 3.3 | 2.2 ± 1.6   |
|           | Harness    | 21.8 ± 2.5 <sup>a</sup> | 14.7 ± 3.5 <sup>ab</sup> | 18.1 ± 2.6 | 3.0 ± 1.2   |
| 4-Person  | Hand       | 20.7 ± 3.0 <sup>b</sup> | 14.1 ± 3.4 <sup>b</sup>  | 18.0 ± 2.1 | 1.6 ± 0.9   |
|           | Harness    | 21.6 ± 3.4 <sup>b</sup> | 15.6 ± 3.7 <sup>a</sup>  | 18.6 ± 1.9 | 2.7 ± 1.0   |

By column, means with different letters are significantly different from each other,  $p < 0.01$ .

**Table 7.** Team size by carry type by gender effects for the four different phases of the 15-min repeated litter-carry (sec).

| Team Size by Carry Type by Gender | n       | Carry   | Dismount & Lift          | Return Run               | Don Harness            |
|-----------------------------------|---------|---|--------------------------|--------------------------|------------------------|
| 2-Person Hand<br>Men<br>Women     | 12<br>9 | 20.2 ± 2.2 <sup>a</sup><br>26.8 ± 5.5 <sup>b</sup>  | 11.7 ± 1.7<br>18.8 ± 4.5 | 16.3 ± 1.6<br>16.1 ± 1.3 | 2.3 ± 1.9<br>2.1 ± 1.0 |
| 2-Person Harness<br>Men<br>Women  | 12<br>9 | 20.4 ± 2.2 <sup>a</sup><br>23.1 ± 2.0 <sup>a</sup>  | 12.6 ± 0.9<br>16.9 ± 3.7 | 16.3 ± 0.9<br>17.1 ± 1.0 | 3.5 ± 1.3<br>2.5 ± 0.8 |
| 4-Person Hand<br>Men<br>Women     | 12<br>9 | 18.3 ± 1.4 <sup>ac</sup><br>23.1 ± 2.1 <sup>a</sup> | 12.1 ± 1.3<br>16.1 ± 4.1 | 21.3 ± 2.8<br>20.1 ± 2.2 | 1.3 ± 0.5<br>1.8 ± 1.2 |
| 4-Person Harness<br>Men<br>Women  | 12<br>9 | 19.3 ± 2.0 <sup>ac</sup><br>24.2 ± 2.5 <sup>a</sup> | 13.9 ± 1.4<br>17.3 ± 5.0 | 19.6 ± 1.7<br>20.0 ± 1.6 | 2.8 ± 1.0<br>2.6 ± 1.2 |

By column, means with different letters are significantly different from each other,  $p < 0.01$ .

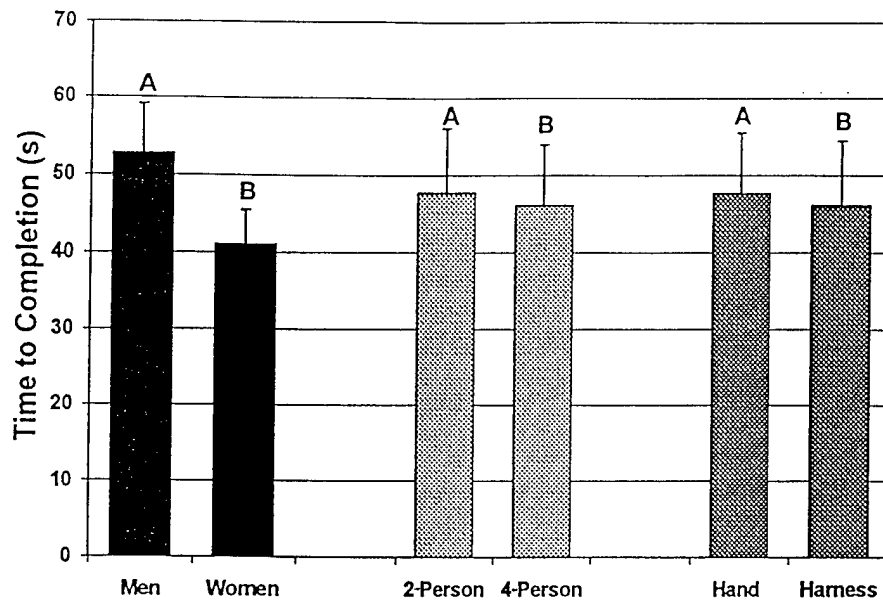
**Table 8.** Team size by gender effects for the four different phases of the 15-min repeated litter-carry (sec).

| Team Size | Gender | Carry      | Dismount & Lift | Return Run              | Don Harness |
|-----------|--------|------------|-----------------|-------------------------|-------------|
| 2-Person  | Men    | 20.3 ± 2.2 | 12.1 ± 1.8      | 16.2 ± 1.4 <sup>a</sup> | 2.2 ± 1.6   |
|           | Women  | 24.9 ± 4.5 | 17.8 ± 4.1      | 20.7 ± 2.5 <sup>b</sup> | 3.0 ± 1.2   |
| 4-Person  | Men    | 18.7 ± 1.7 | 13.0 ± 1.6      | 16.7 ± 1.0 <sup>a</sup> | 1.6 ± 0.9   |
|           | Women  | 23.6 ± 2.3 | 16.7 ± 4.5      | 19.8 ± 1.7 <sup>c</sup> | 2.7 ± 1.0   |

By column, means with different letters are significantly different from each other,  $p < 0.05$ .

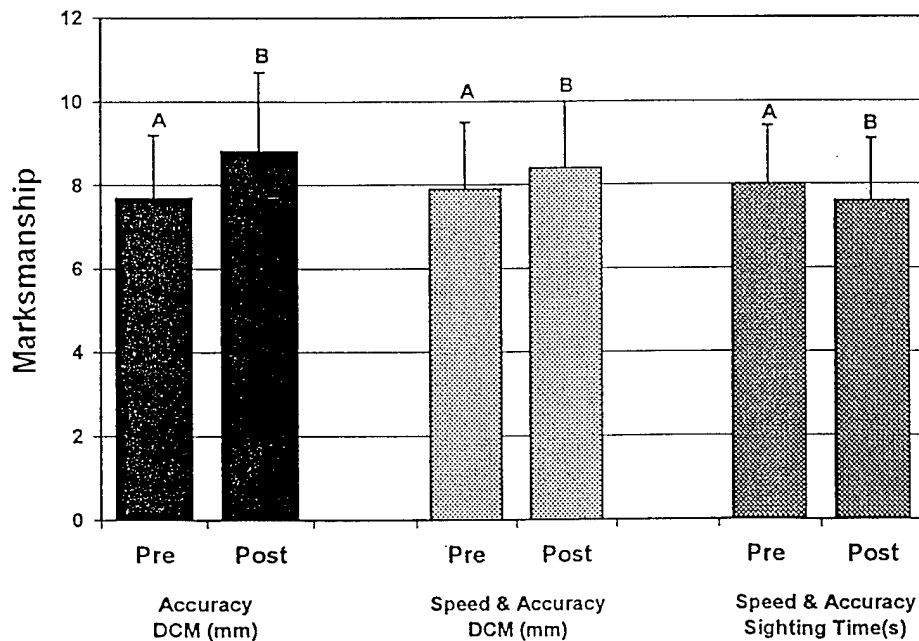


**Figure 6.** Cord and cylinder task: main effects for gender, team size and harness.



By pairs, means with different letters differ from each other, ( $p < 0.05$ ).

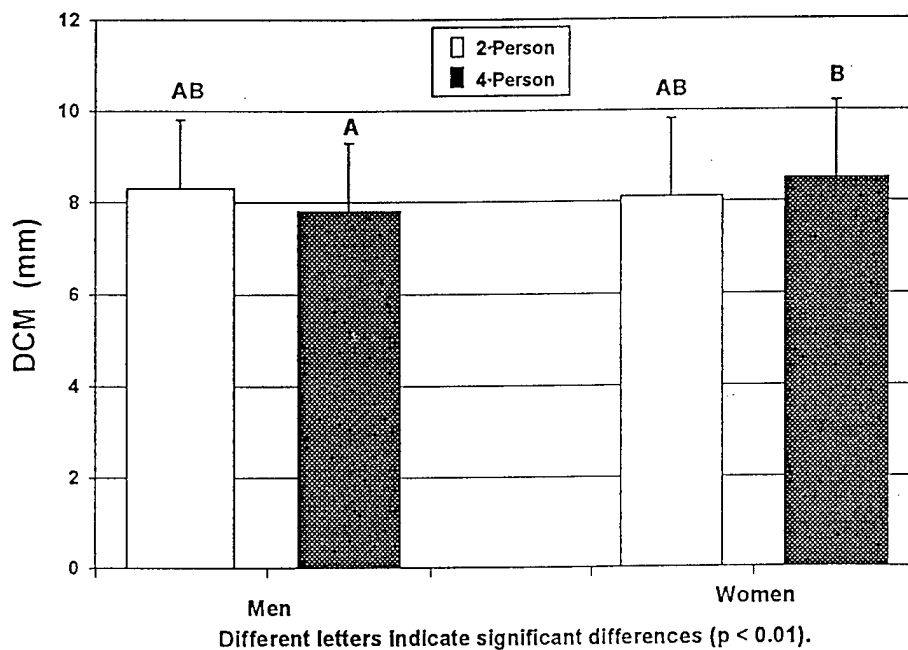
**Figure 7.** Marksmanship: distance from center of mass (DCM) for accuracy, speed and accuracy, and sighting time main effects.



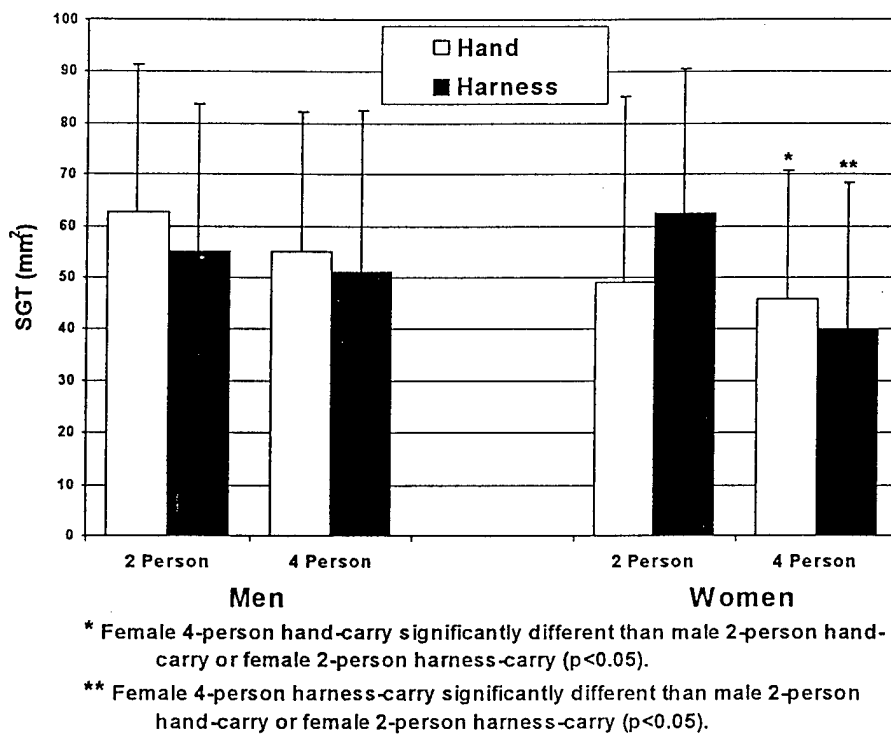
By pairs, means with different letters differ from each other ( $p < 0.05$ ).

A team size x gender interaction for DCM speed and accuracy ( $p = 0.02$ ) showed that male, 4-person teams had a smaller DCM than female, 4-person teams; but scores were not significantly different from male or female, 2-person teams (Figure 8). A significant harness x team size x gender interaction effect ( $p = 0.02$ ) for shot group tightness when shooting for speed and accuracy was demonstrated. Post hoc analyses showed female, 4-person teams (hand- and harness-carry) had the tightest shot groups, and female, 2-person, harness and male, 2-person, hand-carry groups had the most disperse shot groups (Figure 9).

**Figure 8.** Marksmanship: distance from center of mass (DCM) for speed and accuracy for gender x team size interaction.



**Figure 9.** Marksmanship: shot group tightness (SGT) for speed and accuracy for gender x harness x team size interaction.

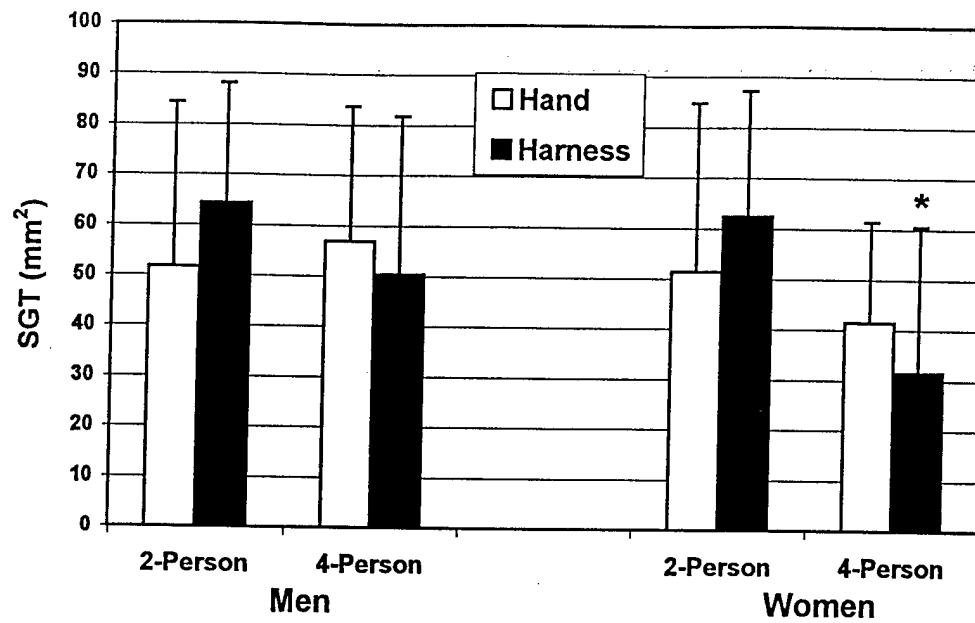


A four-way interaction was found between pre/post x harness x team size x gender for SGT ( $p = 0.04$ ). Post hoc analyses showed differences existed during the post-carry shooting sessions. Post-carry, women carrying in 4-person teams with a harness had tighter shot groups than male and female, 2-person teams with a harness (Figure 10).

## LITTER MOTION

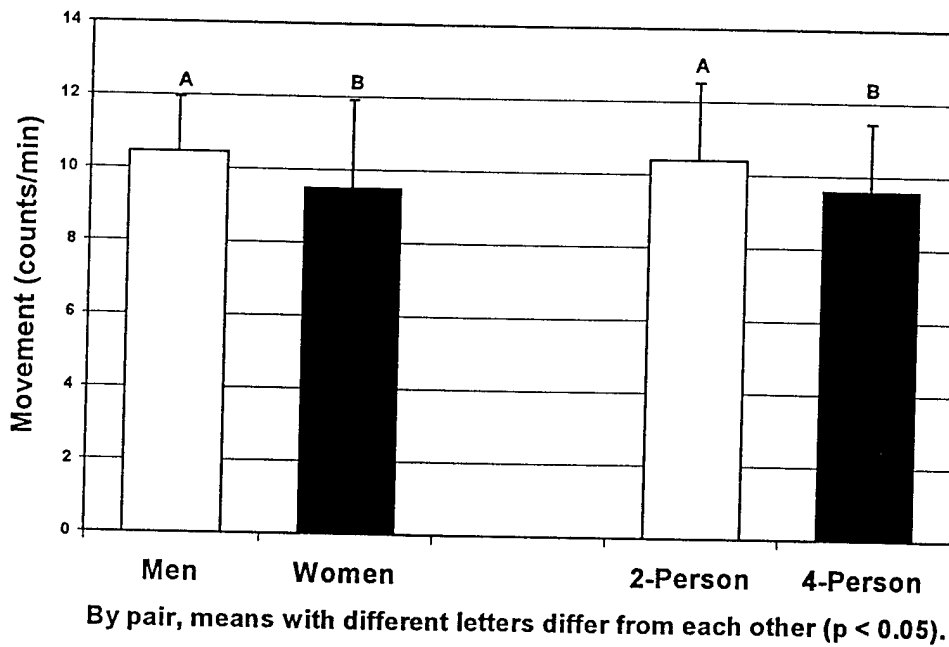
Litter movement was greater in male vs. female teams ( $p = 0.02$ ) and in 2- vs. 4-person teams ( $p < 0.0001$ ; Figure 11).

**Figure 10.** Post-exercise marksmanship: shot group tightness (SGT) for gender x harness x team size.



\*Significantly different from male and female 2-person harness carries ( $p < 0.05$ ).

**Figure 11.** Litter movement: main effects for gender and team size.



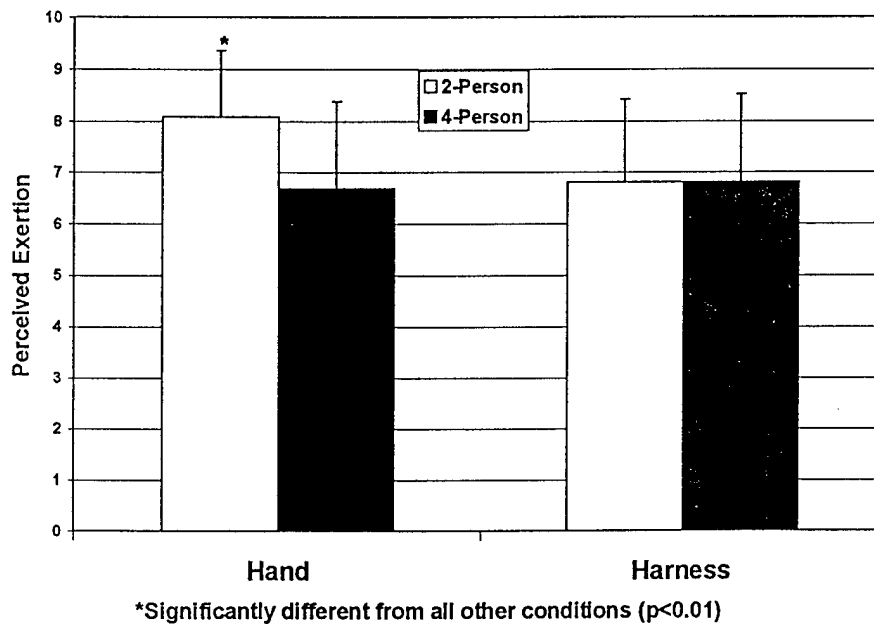
## HEART RATE

Heart rate was slightly lower for both genders combined (Hand-carry:  $182.8 \pm 8.2$  beats per min vs. Harness-carry:  $180.1 \pm 8.1$  beats per min) when using a harness ( $p = 0.03$ ). This decrease in heart rate is of little practical significance.

## PERCEIVED EXERTION

A harness x team size interaction was noted for RPE ( $p = 0.01$ ). The 2-person hand-carry teams reported greater perceived exertion than any other team size x harness combination (Figure 12).

**Figure 12.** Ratings of perceived exertion: harness x team size interaction.



## **SORENESS, PAIN, AND DISCOMFORT (SPD)**

The soreness, pain, and discomfort (SPD) ratings were broken down into 11 component parts for both the front and back of the body. Main effects for gender, harness use, and team size can be seen in Table 9. Women reported greater SPD than men in the palm and dorsal shoulder. Greater SPD were reported during hand-carries in the anterior lower arm, hand, and foot; and in the dorsal shoulder, upper arm, and foot (Table 9). Greater SPD were reported when using a harness (compared with not using a harness) on the dorsal aspect of the lower arm. The 4-person teams reported greater SPD in the anterior arm and calves, while 2-person teams had greater SPD in the palm, dorsal head/neck and dorsal foot areas.

Several harness x gender interactions were found. Women carrying litters by hand reported greater SPD in their palms ( $p < 0.01$ ), dorsal shoulder ( $p < 0.01$ ), upper arm ( $p < 0.01$ ), and lower arm ( $p < 0.05$ ) than women with a harness and men with or without a harness. Women carrying with a harness also reported more SPD in the dorsal shoulder area, than men carrying with or without a harness ( $p < 0.05$ ).

Several team size x gender interactions were noted. The 2-person, female teams reported greater SPD in their palms than any other gender x team size combination ( $p < 0.01$ ). Greater SPD in the palm area was also reported by 4-person, female teams compared to male 2- or 4-person teams ( $p < 0.05$ ).

Two significant harness x team size interactions were found. The 2-person, hand-carry teams reported greater palm and dorsal lower arm SPD than any other harness x team size combination ( $p < 0.01$ ), while 4-person, hand-carry teams had greater SPD in the palm area than 4-person teams using a harness ( $p < 0.05$ ).

**Table 9.** Soreness, Pain, and Discomfort (SPD): main effects (anterior/posterior, p value).

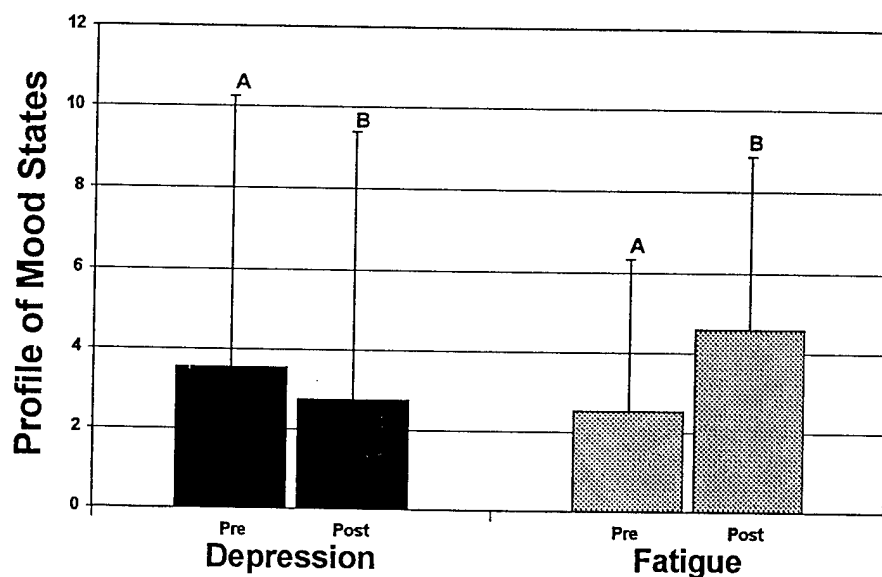
| Area of Discomfort   | > Women<br>< Men | > Hand-carry<br>< Harness-carry | > Harness-carry<br>< Hand-carry | > 2-person<br>< 4-person | > 4-person<br>< 2-person |
|----------------------|------------------|---------------------------------|---------------------------------|--------------------------|--------------------------|
| Neck                 | NS/NS            | NS/NS                           | NS/NS                           | NS/0.04                  | NS/NS                    |
| Shoulder             | NS/0.03          | NS/0.01                         | NS/NS                           | NS/NS                    | NS/NS                    |
| Upper Arm            | NS/NS            | NS/0.03                         | NS/NS                           | NS/NS                    | 0.04/NS                  |
| Lower Arm            | NS/NS            | 0.05/NS                         | NS/0.03                         | NS/NS                    | NS/NS                    |
| Hand                 | 0.007/NS         | 0.0003/NS                       | NS/NS                           | 0.002/NS                 | NS/NS                    |
| Upper Back           | NS/NS            | NS/NS                           | NS/NS                           | NS/NS                    | NS/NS                    |
| Middle Back          | NS/NS            | NS/NS                           | NS/NS                           | NS/NS                    | NS/NS                    |
| Lower Back/Sacrum    | NS/NS            | NS/NS                           | NS/NS                           | NS/NS                    | NS/NS                    |
| Thigh (include knee) | NS/NS            | NS/NS                           | NS/NS                           | NS/NS                    | NS/NS                    |
| Lower Leg (calves)   | NS/NS            | NS/NS                           | NS/NS                           | NS/NS                    | 4.3/0.03                 |
| Feet                 | NS/NS            | 0.02/0.02                       | NS/NS                           | NS/0.03                  | NS/NS                    |

> means that this effect was greater for the variable it precedes. < means that this effect was less for the variable it precedes. For example, in the first column > women and < men mean that the areas of discomfort were significantly greater for women than for men.

## PROFILE OF MOOD STATES (POMS)

No significant differences were found for tension, anger, vigor, or confusion scales. A marginally significant finding for team size indicated that participants were more fatigued in the 2-person carry compared to the 4-person carry (2-person:  $4.3 \pm 4.8$ , 4-person:  $2.8 \pm 3.1$ ;  $p = 0.05$ ). Participants reported being less depressed ( $p = 0.01$ ) and more fatigued after completing the litter carry ( $p = 0.002$ ; Figure 13). Greater fatigue was reported after the 2-person carry than any other administration (pre/post) x team size combination ( $p = 0.04$ ).

**Figure 13.** Profile of Mood States (POMS): main effects for pre/post ratings of depression and fatigue.



By pair, means with different letters are different from each other ( $p < 0.05$ ).

## ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE (ESQ)

Physical symptoms reported post-carry (as opposed to pre-carry) included being short of breath, a fast heart beat, hands shaking/trembling, legs/feet aches, profuse sweating, and dry mouth (Table 10). Women reported more shaking/trembling of



**Table 10.** Environmental Symptoms Questionnaire (ESQ): main effects (p value).

| Symptom                     | > Post<br>< Pre | > Women<br>< Men<br><i>post-carry</i> | > Hand-carry<br>< Harness-carry<br><i>post-carry</i> | > 2-person<br>< 4-person<br><i>post-carry</i> |
|-----------------------------|-----------------|---------------------------------------|--|---|
| Hands shaking/<br>trembling | = 0.0001        | < 0.01                                | NS   | NS  |
| Hand/arm/<br>shoulder ache  | NS              | NS                                    | < 0.05   | < 0.01  |
| Legs/feet ache              | = 0.0004        | NS                                    | NS   | NS  |
| Short of breath             | = 0.001         | NS                                    | NS   | NS  |
| Fast heart beat             | < 0.0000        | NS                                    | NS   | NS  |
| Profuse sweating            | < 0.0000        | NS                                    | NS   | NS  |
| Dry mouth                   | < 0.0000        | NS                                    | NS   | NS  |
| Light-headed                | NS              | NS                                    | < 0.05   | NS  |

> means that this effect was greater for the variable it precedes. < means that this effect was less for the variable it precedes. For example, in the first column > post and < pre means that the environmental symptom listed was reported as significantly greater post-carry as compared with a lower report pre-carry.

their hands post-carry than did men. Physical symptoms that were greater after a hand-carry, as opposed to a harness-carry, included feeling light-headed and having hand/arms/shoulders ache.

The 2-person teams reported greater post-carry hand/arm/shoulder aches than 4-person teams ( $p < 0.01$ ). The 2-person, hand-carry teams reported feeling more light-headed after carrying than other team size x harness combinations ( $p < 0.05$ ).

## **DISCUSSION: REPEATED CARRY**

### **GENERAL EXERCISE**

Repeated litter-carrying is a physically demanding task, as evidenced by the near maximal heart rates and fatigue. The reported subjective symptoms revealed increased symptoms post-carry and substantiated the considerable physical demands of litter-carrying. Carrying a litter immediately prior to firing a M-16 rifle resulted in a decrease in both men's and women's rifle marksmanship scores for accuracy alone, and speed and accuracy combined, while sighting time for speed and accuracy was faster. A faster sighting time while maintaining accuracy would be advantageous. However, like various other stressors such as acute high altitude ascent and exposure (31), carrying a backpack (32), and marching in the MOPP overgarment with boots in a desert environment (33), shooters' accuracy decreased, in part, because they did not take the time necessary to accurately sight the rifle.

The decrease in rifle marksmanship scores following the litter-carry was probably due to the high metabolic demands of the carry and consequent elevated body temperatures. Although the carry was self-paced, volunteers were instructed to "retrieve as many patients as possible" and the walking/running speeds ranged from 4.8 to 20.9 km/hr. Previous research documented the negative effects of aerobic exercise on marksmanship accuracy (6,13,34) due to increased heart rate and body sway directly caused by the exercise (22). In addition to local hand and arm fatigue induced by the sustained contraction of the hand flexors, the simulation

of lifting the patient into an ambulance required a heavy lift (45-kg) and produced additional muscle fatigue in the arms and shoulders, thereby making it difficult to stabilize the rifle for accurate aiming.

## **GENDER**

Men carried more litters, completed more lifts, and completed each element of the cycle time except donning the harness and picking up the harness (i.e., carry, lift, return for the next patient) faster than women, probably as a result of their greater strength and aerobic capacity. The maximum aerobic capacity of women was 57.0%, grip strength was 69%, and upper body strength measured by bench press was 45% that of the men. Neither increasing team size from a 2- to a 4-person carry, nor using a harness enabled women to complete carries of as many simulated casualties as men. Mixed-gender teams were not used in this study. Results of a study requiring volunteers to lift and carry weights for a distance of 7.2 meters support the fact that mixed-gender teams can handle more absolute weight (29). It is reasonable to assume that the capacity of mixed-gender litter-carrying teams would also be greater than all female teams and less than all male teams.

Overall, men performed better on strength-based tasks and women performed better on the fine-motor task. The fact that men are stronger than women is well supported in the literature. However, the idea that women may perform fine-motor tasks quicker than men is not substantiated by norms for the Purdue Pegboard and O'Connor Finger Dexterity Tests (examiners manual available from Lafayette Instrument Company, P.O. Box 5729, Lafayette, IN 47903).

More litter movement was seen during carries by male teams, resulting from the faster, more frequent carries completed by men. Overall, women reported more SPD post-carry than men, accentuating the idea that the physical demands affected women more than the men.

## **HARNESS**

Use of a harness increased the time it took to pick up the litter. As a result, men

completed less carries when using a harness, and several men voiced frustration of not completing as many carries as they thought they should have accomplished. The increase in the time to pick up the litter did not change the number of carries that women completed. Although women did not complete a significantly greater number of carry cycles when using a harness, they were able to carry the litter faster when using a harness. Use of a harness allowed women to carry the litter as fast as men under comparable conditions (in 2- and 4-person teams).

Using a harness- vs. a hand-carry resulted in faster completion of the fine-motor coordination task. It appears that the harness helped to disperse the weight of the litter and reduced the requirement for sustained hand contractions, as it was designed to do. As a result, fine-motor coordination was improved, and the amount of SPD reported in the shoulders, upper arms, and palms was less when using a harness. In addition, women reported less SPD when using a harness.

Harness use resulted in a slightly lower heart rate for men and women and reduced the overall reported SPD reported. In a 2-person team, harness use reduced the perception of effort to that experienced by a 4-person team. Volunteers felt more light-headed and their hand/shoulders/arms ached more after hand- vs. harness-carries. The feelings of being light-headed may have been greater for hand-carries due to the sustained hand-grip contractions invoking a pressor response. At tensions above 15% maximal voluntary contraction, a pressor response results in an approximate linear rise in heart rate, cardiac output, and blood pressure, with the extent of the cardiovascular response determined by the intensity of the contraction and its duration (11,17). The hand-grip requirements of carrying 22.5 kg in each hand required women to exert approximately 64% and men to exert approximately 44% of their maximal grip strength effort.

## **TEAM SIZE**

Use of 4-person teams resulted in faster completion of the carry phase of the 15 min carry and faster completion of the fine-motor task. Use of 4-person teams helped to reduce both overall physical demands and sustained hand-contractions, as each team member carried half of the 45-kg head of the litter (22.5 kg) and could

use two hands to carry the weight. The resultant decrease in local fatigue, as well as overall physical demands, helped to maintain fine-motor coordination, which is important to a medic. Furthermore, women working in 4-person teams ran faster to retrieve the next patient compared to working in 2-person teams. There were no differences for men by team size concerning the run to retrieve the next patient.

Carrying in 4-person teams reduced localized and general fatigue as seen by lower reports of hand/arm/shoulder achiness, overall SPD and fatigue. The patterns of SPD were different for 2- and 4-person teams, with more SPD reported in the anterior upper arms and calves for 4-person teams. The SPD in the anterior upper arms and calves may have been the result of having to adjust to the resistance of the other team member. Carrying in 4-person teams resulted in both team members leaning away from the center and was especially evident when women worked in 4-person teams. More SPD was reported in the neck and hands when carrying in 2-person teams. In addition, 2-person teams also experienced greater hand/arm/shoulder achiness post-carry, as reported on the ESQ.

Women's post-carry rifle marksmanship scores were better for 4-person teams than for 2-person teams. Men's post-carry scores did not improve by increasing team size. It appears that the high physical demands of the task, both local and general, were such that women benefitted from the increase in team size. The mean time that volunteers carried the litter (during the first portion of the 15 min carry) was  $19.5 \pm 2.1$  sec for men and  $24.3 \pm 3.6$  sec for women. Thus, the carry portion of the cycle represented 7.8% of mens' and 22.7% of womens' sustained hand-carry time. This would indicate that greater localized fatigue may have resulted for women, which is supported by female, 2-person teams having reported more SPD in their palms than other gender x team size combinations, and female, 4-person teams reported more SPD in their palms than men. Overall fatigue also appears to have been greater for female, 2-person teams, as the return portion of their carry cycle was the slowest. Observation revealed that this phase (returning for the next patient) was used as recovery time, when needed.

## **TEAM SIZE X HARNESS**

The 4-person, hand-carry teams completed more carries and lifts than all other team size x harness combinations. Sharing the load in 4-person teams reduced the physical demand of the task. This fact, along with the increased time it took to pick up the litter and attach it to the harness, probably accounted for more 4-person hand-carries being completed than harness-carries.

With respect to rifle marksmanship, carrying in 4-person teams regardless of gender and/or harness use likely accounted for less fatigue leading to volunteers' marksmanship accuracy to be better than when shooting in 2-person teams. Furthermore, when litter-carrying in 4-person teams, the load at one's own end of the litter is shared with a partner. Therefore, the physical stress for half the individuals will be less than maximum because they will be limited by the rate at which the slower partner can work.

The 2-person, hand-carry teams reported greater perceived exertion. Use of a harness while carrying in a 2-person team greatly reduced the perception of effort, making it feel similar to carrying in a 4-person team either with or without a harness. Although both men and women perceived the 2-person carry as requiring less exertion when using a harness, only the women stated they would use a harness for a mass-casualty situation if it was available. The greatest SPD was reported for 2-person, hand-carry teams in their palms and dorsal lower arms of all the team size x harness conditions, emphasizing the strain incurred by the flexor muscles during hand-carries. The 2-person, hand-carry teams also reported greater feelings of being light-headed post-carry, compared to other team size x harness conditions, again indicating the possibility of a pressor response occurring.

## **CONCLUSIONS: REPEATED CARRY**

Gender, team size, and harness use affected soldiers' abilities to transport, defend, and medically treat their patients. Men were able to carry and load more

patients in a given time period than women, and women reported greater SPD than men. Carrying in 4-person rather than 2-person teams increased the number of carries completed, improved post-carry, fine-motor performance, and reduced subjective reports of fatigue, SPD, and hand/arm/shoulder aches for both men and women. Women's marksmanship scores also benefitted from carrying in 4-person teams. Harness use did not increase the number of simulated casualties that could be evacuated. However, using a harness rather than carrying the litter by hand improved post-carry, fine-motor performance, lowered volunteers' heart rates, and reduced subjective reports of SPD and feelings of being light-headed for both men and women. The 2-person hand-carries were perceived as requiring the greatest exertion and resulted in greater SPD and feelings of being light-headed post-carry.

Recommendations regarding a mass-casualty scenario include the following:

- 1) The policy of having soldiers work in 4-person teams should remain and be enforced.
- 2) A harness system should be included with litter distribution for exigencies requiring 2-person teams, as the overall physical demands (indicated by slightly lower heart rates and light-headedness) were reduced by harness use.
- 3) Harness use should be optional, as harness use is more beneficial for women than for men.
- 4) To remove the greatest number of casualties in the shortest period of time, 4-person, male teams should be used.

## RESULTS: CONTINUOUS CARRY

### TIME OF CARRY

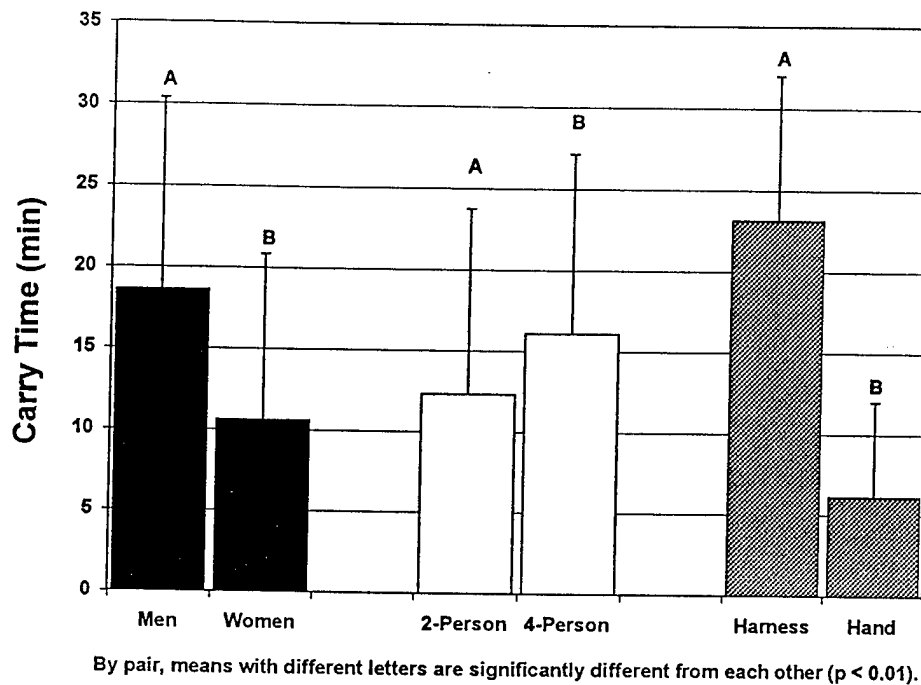
The times to complete the carries are in Table 11 and main effects can be seen in Figure 14. Men carried the litter for a longer period of time than women.

**Table 11.** Continuous carry times (min) for men and women.

| CARRY TYPE             | MEN<br>Mean $\pm$ S.D.<br>(Range) | WOMEN<br>Mean $\pm$ S.D.<br>(Range) |
|------------------------|-----------------------------------|-------------------------------------|
| 2-Person Hand-carry    | 4.2 $\pm$ 1.8<br>(2.1 - 8.4)      | 1.8 $\pm$ 1.0<br>(1.1 - 4.5)        |
| 2-Person Harness-carry | 26.4 $\pm$ 5.6<br>(16.9 - 30)     | 17.1 $\pm$ 9.3<br>(6.0 - 30.0)      |
| 4-Person Hand-carry    | 13.9 $\pm$ 6.9<br>(6.7 - 30.0)    | 4.7 $\pm$ 1.2<br>(3.3 - 6.8)        |
| 4-Person Harness-carry | 30.0 $\pm$ 0<br>(30.0)            | 24.0 $\pm$ 10.5<br>(9.3 - 30.0)     |



**Figure 14.** Carry time: main effects for gender, team size and harness condition.

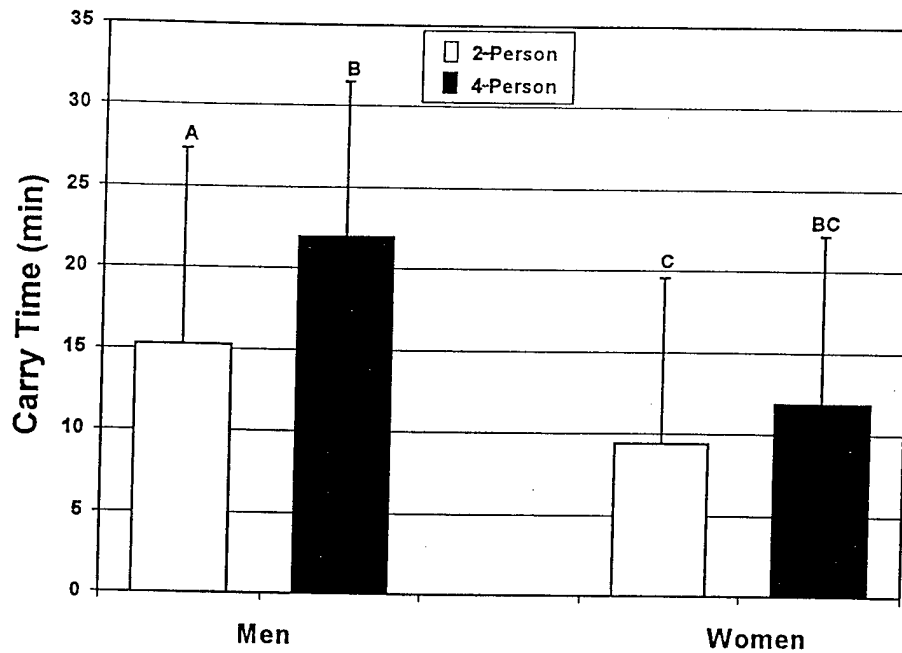


The 4-person teams carried the litter longer than 2-person teams. Both men and women carried the litter longer with vs. without a harness. A post hoc analysis of a team size x gender interaction ( $p = 0.02$ ) revealed that male, 4-person teams carried the litters longer than any other team size x gender combination and that male, 2-person teams carried the litter longer than female, 2-person teams (Figure 15).

## FINE-MOTOR COORDINATION

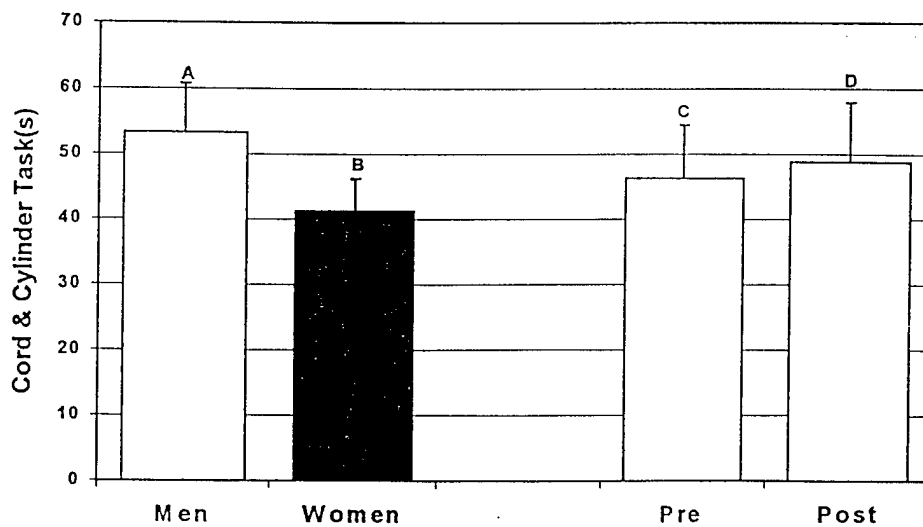
Women completed the cord and cylinder task faster than men, and task performance was slower post-carry, compared with pre-carry (Figure 16). A harness x pre/post interaction ( $p = 0.03$ ) demonstrated that participants completed the cord and cylinder task more slowly after carrying the litter in their hands, however, there was no pre- to post-difference when using a harness (Figure 17).

**Figure 15.** Carry time: gender x team size interaction.



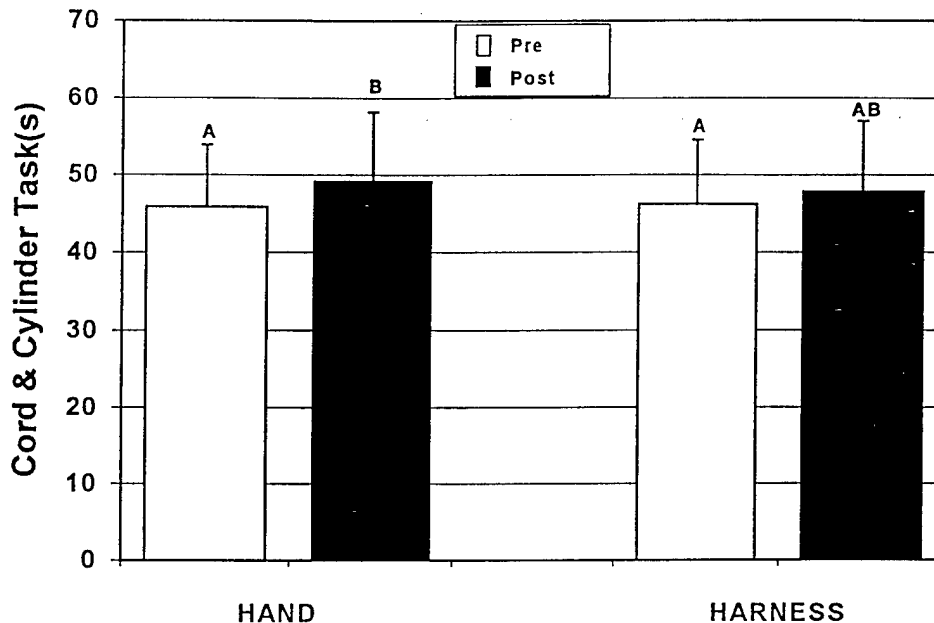
Means with different letters are significantly different from each other ( $p < 0.01$ ).

**Figure 16.** Cord and cylinder task: main effects for gender and pre-/post-carry differences.



For each pair, means with different letters differ from each other ( $p < 0.01$ ).

Figure 17. Cord and cylinder task: harness x pre-/post-carry interaction.



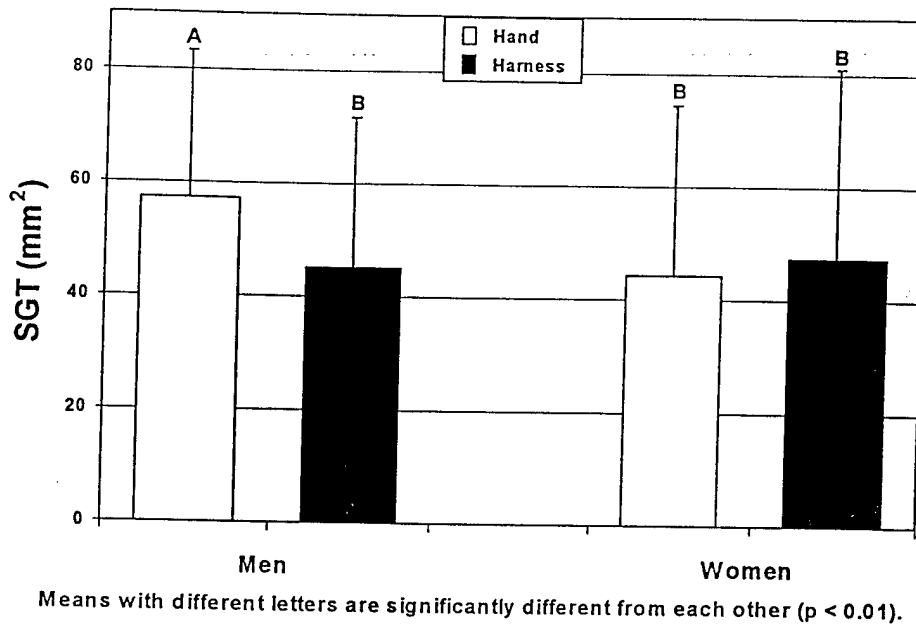
Means with different letters are significantly different from each other ( $p < 0.05$ ).

## MARKSMANSHIP

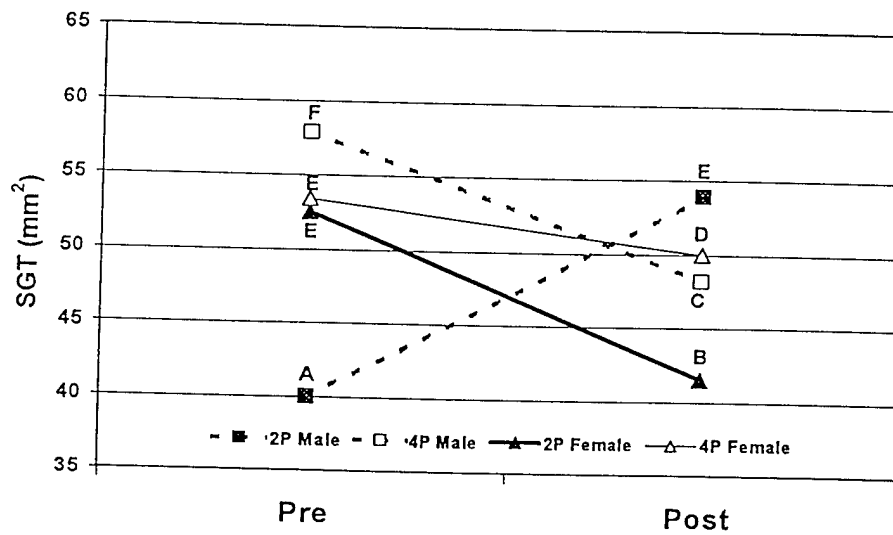
Post-carry rifle marksmanship was less accurate when shooting for accuracy only as depicted by DCM (pre-carry:  $7.8 \pm 1.6$  mm, post-carry:  $8.1 \pm 1.7$  mm;  $p = 0.02$ ) across all conditions. Although no overall harness effect was noted, a gender x harness interaction ( $p = 0.02$ ) for SGT when shooting for accuracy only revealed that men carrying with their hands had the most dispersed shot group (Figure 18).

A pre-/post-carry x team size x gender interaction was demonstrated ( $p = 0.04$ ) for speed and accuracy SGT, with each post-carry score differing significantly from the others (Figure 19). Male, 2-person teams were the only teams whose SGT scores were degraded post-carry, and the post-carry scores were lower than other gender x team size combinations (Figure 19).

**Figure 18.** Marksmanship: shot group tightness (SGT) when shooting for accuracy only, gender x harness interaction.



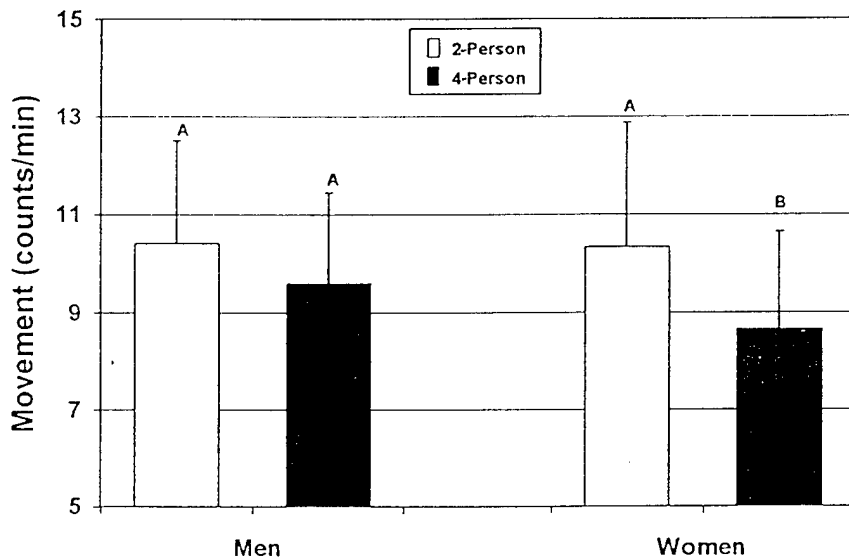
**Figure 19.** Marksmanship: shot group tightness (SGT) when shooting for speed and accuracy, gender x team size x pre-/post-carry interaction.



## LITTER MOTION

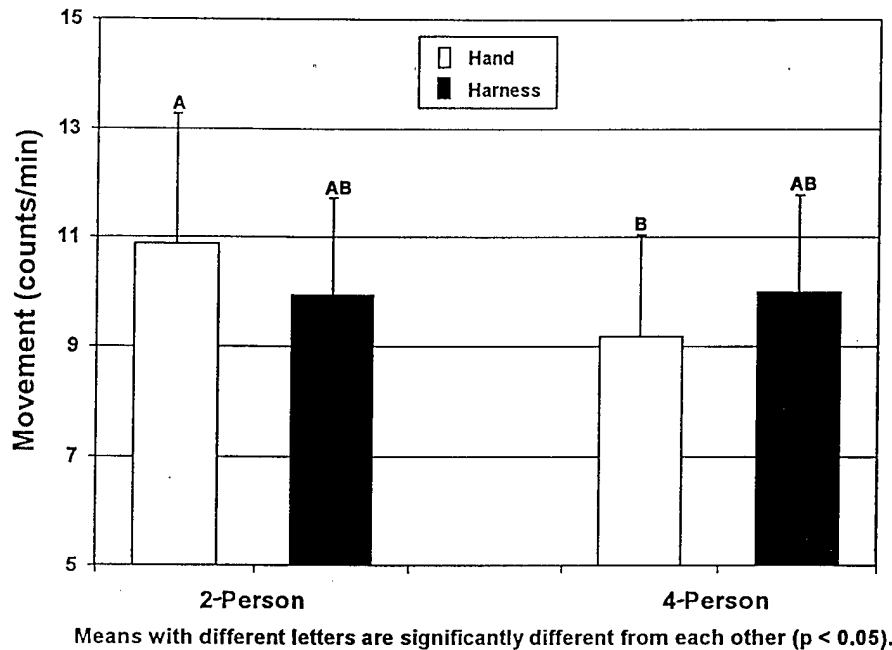
Neither gender nor harness use had a main effect on litter movement (counts/min). Litter movement was less for 4- vs. 2-person teams ( $9.6 \pm 1.9$  vs.  $10.4 \pm 2.1$  counts/min;  $p = 0.01$ ). A team size x gender interaction ( $p = 0.01$ ) indicated that female, 4-person teams carried the litter more smoothly than did any other gender x team size combination (Figure 20). A team size x harness interaction ( $p = 0.02$ ) indicated that litter movement was greater in 2-person, hand-carry teams than 4-person, hand-carry teams (Figure 21).

**Figure 20.** Litter movement: gender x team size interaction.



Means with different letters are significantly different from each other ( $p < 0.05$ ).

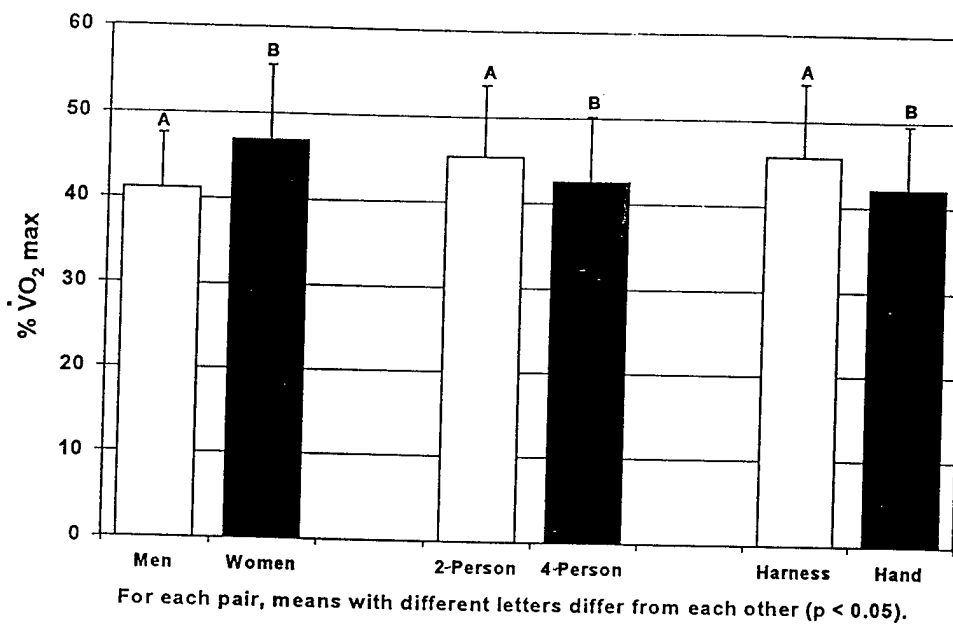
**Figure 21.** Litter movement: harness x team size interaction.



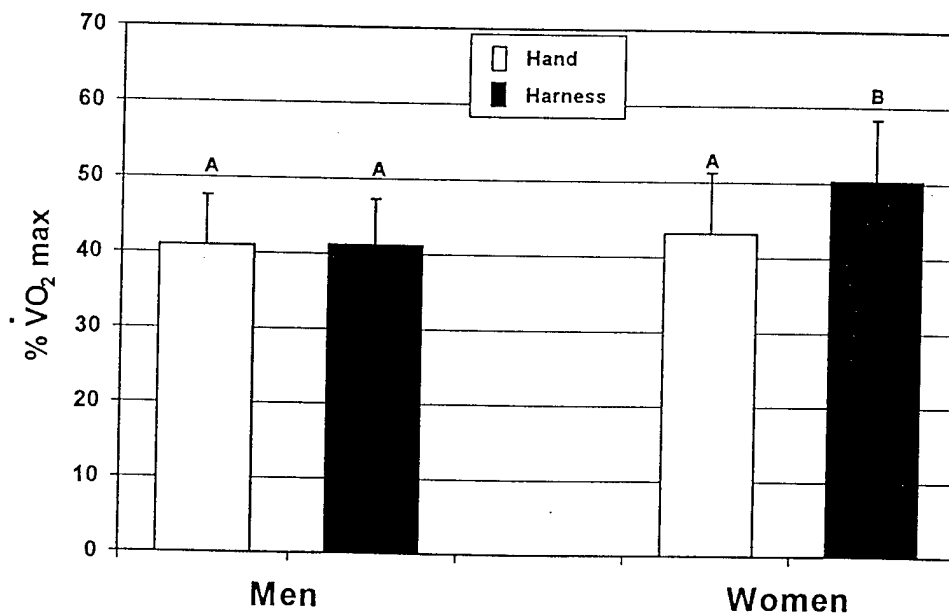
## HEART RATE AND OXYGEN UPTAKE

Women performed the task at a higher  $\%V_{O_2\max}$  and heart rate ( $\%V_{O_2\max}$   $46.8 \pm 8.8\%$ , heart rate:  $158.2 \pm 10.9$  beats per min) than men ( $\%V_{O_2\max}$   $41.1 \pm 6.4\%$ , heart rate:  $133.6 \pm 11.9$  beats per min). Soldiers exercised at a higher  $\%V_{O_2\max}$  during harness-carries (Figure 22). No overall team size effect was observed for heart rate; however, 2-person teams worked at a higher  $\%V_{O_2\max}$  than 4-person teams. A gender x team size interaction was found ( $p = 0.008$ ), with differences in heart rate primarily being a function of gender; that is, heart rate of women is greater than that of men. Women using a harness exercised at a greater  $\%V_{O_2\max}$  than other gender x harness combinations (Figure 23). Heart rate was greater during hand-carries than while using a harness ( $149.8 \pm 17.9$  vs.  $141.9 \pm 14.7$  beats per min;  $p = 0.01$ ).

**Figure 22.** Exercise intensity: main effects for gender, team size, and harness.



**Figure 23.** Exercise intensity: gender x harness interaction.



Means with different letters are significantly different from each other (p < 0.05).

## **PERCEIVED EXERTION**

There was no difference in perceived exertion for men vs. women while performing the litter-carry. Less subjective exertion was reported after carrying the litter in the hands than with a harness ( $5.3 \pm 2.2$  vs.  $6.2 \pm 1.9$ ).

## **SORENESS, PAIN, AND DISCOMFORT (SPD)**

Greater SPD was reported when carrying with a harness in the anterior head/neck, shoulder, and chest; and the dorsal head/neck, shoulder, chest, thigh, and calf. Greater SPD was reported when carrying without a harness in the anterior forearm and hand, and posterior forearm and hand (Table 12). The 2-person teams reported more SPD than 4-person teams in the dorsal neck and shoulder. The 4-person teams reported greater SPD than 2-person teams in the lower back (Table 12).

Several harness x team size effects were noted. Anterior chest and shoulder pain, and posterior neck and upper back SPD were greater for 2-person teams carrying with a harness than for other team size x harness combinations. In addition, more posterior neck SPD was reported for harness compared to non-harness conditions regardless of team size ( $p < 0.01$ ). The 2-person, hand-carry teams had less SPD in their lower back than any other harness x team size combination ( $p < 0.05$ ).

## **PROFILE OF MOOD STATES (POMS)**

No significant differences were found for any of the POMS.

## **ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE (ESQ)**

Physical symptoms reported as being greater in intensity post-carry (compared with pre-carry), and main effects for gender, harness use, and team size can be seen in Table 13. Women gave higher subjective ratings for post-carry rapid heart



**Table 12.** Soreness, Pain, and Discomfort (SPD): post-carry main effects (anterior/posterior, p value).

| Area of Discomfort           | >Women<br><Men | > Hand-carry<br><Harness-carry | >Harness-carry<br>< Hand-carry | > 2-person<br>< 4-person | > 4-person<br>< 2-person |
|------------------------------|----------------|--------------------------------|--------------------------------|--------------------------|--------------------------|
| Neck                         | NS/NS          | NS/NS                          | 0.004/ <0.0001                 | NS/<0.0001               | NS/NS                    |
| Shoulder                     | NS/NS          | NS/NS                          | 0.003/ <0.0001                 | NS/0.005                 | NS/NS                    |
| Upper Arm                    | NS/NS          | NS/NS                          | NS/NS                          | NS/NS                    | NS/NS                    |
| Lower Arm                    | NS/NS          | NS/NS                          | NS/NS                          | NS/NS                    | NS/NS                    |
| Hand                         | 0.03/NS        | 0.002/0.0003                   | NS/NS                          | NS/NS                    | NS/NS                    |
| Chest/Upper Back             | NS/0.001       | <0.0001/ 0.002                 | 0.03/0.002                     | NS/NS                    | NS/NS                    |
| Waist/Lower Back             | NS/NS          | NS/NS                          | NS/NS                          | NS/NS                    | NS/0.01                  |
| Pelvis/ Low Back &<br>Sacrum | NS/NS          | NS/NS                          | NS/NS                          | NS/NS                    | NS/NS                    |
| Thigh (Include Knee)         | NS/NS          | NS/NS                          | NS/0.03                        | NS/NS                    | NS/NS                    |
| Lower Leg (Calves)           | NS/NS          | NS/NS                          | NS/0.03                        | NS/NS                    | NS/NS                    |
| Feet                         | NS/NS          | NS/NS                          | NS/NS                          | NS/NS                    | NS/NS                    |

**Table 13.** Environmental Symptoms Questionnaire (ESQ): subjective ratings main effects (p value).

| Symptom                       | >Post<br><Pre | >Women<br><Men | > Hand-carry<br><Harness-carry | >Harness-carry<br>< Hand-carry | > 2-person<br>< 4-person | > 4-person<br>< 2-person |
|-------------------------------|---------------|----------------|--------------------------------|--------------------------------|--------------------------|--------------------------|
| Hands<br>Shaking/Trembling    | <0.0001       | <0.01          | <0.01                          | NS                             | NS                       | <0.01                    |
| Hands/Arms/<br>Shoulders Ache | <0.0001       | NS             | NS                             | NS                             | <0.01                    | NS                       |
| Legs/Feet Ache                | NS            | NS             | NS                             | NS                             | NS                       | NS                       |
| Back Ache                     | <0.0001       | NS             | NS                             | NS                             | NS                       | NS                       |
| Muscles Tight/Stiff           | =0.002        | /NS            | NS                             | NS                             | NS                       | NS                       |
| Short of Breath               | =0.03         | NS             | NS                             | NS                             | NS                       | NS                       |
| Fast Heart Rate               | =0.002        | <0.01          | NS                             | <0.01                          | NS                       | NS                       |
| Profuse Sweating              | =0.001        | NS             | NS                             | <0.01                          | NS                       | NS                       |
| Dry Mouth                     | =0.0001       | NS             | NS                             | <0.01                          | NS                       | NS                       |
| Light-Headed                  | =0.03         | NS             | NS                             | <0.01                          | <0.01                    | NS                       |

beat and hands shaking/trembling. Teams carrying with a harness reported greater post-carry rapid heartbeat, sweating, dry mouth, and light-headedness, while teams carrying by hand reported greater post-carry shaking/trembling of their hands. The 2-person teams reported greater post-carry, light-headedness and aching of their hands/arms/shoulders, while 4-person, post-carry teams reported greater shaking/trembling of their hands.

Female, harness-carry teams reported higher subjective ratings for post-carry rapid heart beat ( $p < 0.05$ ) and back ache ( $p < 0.01$ ) than other gender x harness combinations. Female, 4-person teams reported higher subjective ratings for post-carry, rapid heart beat ( $p < 0.05$ ) than other pre/post x team size x gender combinations. The 2-person, harness teams reported greater post-carry muscle stiffness and hand/arms/shoulder aches ( $p < 0.01$ ) than other team size x harness combinations.

## **DISCUSSION: CONTINUOUS CARRY**

### **GENERAL EXERCISE**

The physical demands of continuous litter-carrying were demonstrated objectively by high heart rates and oxygen uptake while carrying. Post-carry subjective symptoms were also indicative of high physical demands and include short of breath, fast heart beat, profuse sweating, dry mouth, light-headedness, hands trembling, hand/arm/shoulder aches, back aches, and muscle tightness/stiffness.

### **GENDER**

Men carried the litter longer than women. During self reports, women noted a fast heart beat and their hands shaking/trembling post-carry to a greater degree than did men, probably due to greater overall physical demands of the task and less upper-body strength of women.

## HARNESS

Harness use substantially increased the time that a litter could be carried. The harness displaced the physical demands from the hands and arms to the larger muscles of the shoulder and back; therefore, no difference was seen between pre- and post-carry, fine-motor coordination scores or marksmanship scores when using a harness. Hand-carries resulted in local muscular fatigue and slower fine-motor task completion.

Although overall time for hand-carries was shorter than harness-carries, heart rate and oxygen consumption were higher during hand-carries. The higher heart rate may be due to a pressor response generated by the sustained hand contractions, which can occur even during rhythmic exercise with a heavy cardiovascular commitment (16). The higher oxygen use during hand-carries may be an indication that harness use decreased the overall physical demands of the task.

Less exertion was noted following hand-carries, probably a result of the hand-carries being shorter than the harness-carries (6.1 vs. 23.1 min). More SPD were noted in the hand and forearm during hand-carries, and hand-carry teams reported greater post-carry shaking/trembling of their hands on the ESQ. These results illustrate the considerable local fatigue induced by the hand-carries. Harness-carry teams reported more post-carry pain in the neck, shoulder, chest, upper back, thigh, and calves and greater post-carry light-headedness, rapid heartbeat, sweating, and dry mouth. These findings demonstrate the reduction in local hand/arm fatigue and displacement of the load to the shoulders and trunk musculature with harness use, as well as the increased effort required of the longer harness-carries.

Harness use influenced men and women differently. Men had a tighter shot group (accuracy) after harness-carries than after hand-carries. Although men's endurance time was much longer with a harness, men were stopped before reaching their fatigue level. Coupled with the decreased requirement for sustained handgrip during harness use, this may account for the increased accuracy in men following harness-carries as opposed to hand-carries.

Women perceived the task to be more difficult as indicated by the increased symptoms (fast heart beat and back ache) reported for women carrying with a harness. This may be because more women worked to exhaustion than men. For both 2- and 4-person harness-carries, 83% of the men were able to carry for 30 min, while only 36% of the women carried for 30 min.

## **TEAM SIZE**

Team size substantially increased the time that a litter could be carried. The 4-person teams used more oxygen because they carried longer than 2-person teams. This explanation is substantiated by the fact that oxygen uptake was lowest for 2-person, female teams, who had the shortest carry times and typically did not reach steady state.

The 4-person teams had the least litter movement, as measured by the actigraph on the manikin's wrist. More adjustments were probably made during 2-person carries to relieve rapidly fatiguing forearm muscles, and soldiers altered their carry style to enable a smoother, more effective carry with their teammate. In addition, men in 2-person teams would let the litter handles slip to the lower part of their fingers and would then "flip" the handles up, catching them on their forearms and then beginning the cycle again, which also increased litter movement.

Because one soldier had to carry the 45-kg alone, the task resulted in greater light-headedness and hands/arms/shoulders aches for 2-person vs. 4-person teams. When carrying in 2-person teams, especially with a harness, greater SPD occurred in the dorsal neck and shoulder areas due to the load being carried by the shoulders and back. The 4-person teams reported greater SPD in the lower back, probably due to reaching over to use both hands during hand-carries and leaning slightly away from the other litter-bearer during harness-carries.

Team size affected male and female teams differently. Male 4-person teams, and female 2- and 4-person teams all improved SGT post-carry from pre-carry most likely due to lack of physical stress imposed (discussed below) and practice and/or arousal effects. Male 2-person teams had the poorest post-carry speed and

accuracy SGT scores of all gender x team size combinations. The primary factor contributing to the difference between male 2- and 4-person teams was that 100% of 4-person harness teams, but only 67% of 2-person teams completed 30 min and were stopped. Therefore, men did not work to exhaustion during 4-person harness-carries.

Female 2-person teams shot the most accurately (i.e., tighter shot groups) following litter-carrying with regard to the various gender x team size combinations. This probably indicates that the length of the hand-carries were not long enough to disrupt women's marksmanship performance (mean time to complete 2-person hand-carry: women = 1.8 min, men = 4.2 min; time to complete 4-person hand-carry: women = 4.7 min, men = 13.9 min).

The 2-person harness-carry teams experienced the greatest chest, shoulder, neck, and upper back pain, muscle stiffness and hand/arms/shoulder aches, probably due to the heavy load and long carry time. The 2-person hand-carry teams experienced the least lower back pain. These findings demonstrate that the task was the most strenuous for 2-person harness teams, as they carried 45 kg for 21.7 min, and the least strenuous for 2-person hand-carry teams, as they carried 45 kg for 3.0 min.

Both harness use and team size increased the time that volunteers could carry the litter. During the 2-person carry, women carried the litter 9.5 times longer when using a harness, and men carried the litter 6.4 times longer with a harness. In 4-person teams, women carried the litter 5.1 times longer with a harness, and men carried the litter 2.2 times longer with a harness. Men may have been able to carry the litter considerably longer with a harness, but the study design required that they be stopped after carrying for 30 min. As a result of the longer carry time with a harness, the overall physical demands were greater during harness-carries. However, local muscular fatigue of the hands and fingers was greater during the hand-carries, and resulted in earlier termination of the carry than during the harness-carry regardless of gender or team size.

## CONCLUSIONS: CONTINUOUS CARRY

Men were able to carry litters longer than women because they are stronger and have a higher aerobic capacity. Women working in 4-person, hand-carry teams could carry as much as men working in 2-person, hand-carry teams. Women working in 4-person teams with a harness could carry approximately as much as men working in 2-person teams with a harness.

Use of an ergonomically designed harness improved the ability to transport and medically treat patients, and maintained marksmanship accuracy. Harness use decreased the overall physical demands of the task and local fatigue to the hands/arms so that soldiers could carry patients considerably longer.

The 4-person teams also helped increase the time of carries and decreased the overall physiological demand of the task. The 4-person teams were able to maintain pre-carry fine-motor and marksmanship performance. The 2-person teams using a harness carried substantially longer than 4-person teams without a harness.

It is suggested that:

1. The policy of using 4-person teams remain and be enforced,
2. Harnesses be included with litters for situations that require 4-person litter-carrying for 5 continuous min, or 2-person litter-carrying for 2 continuous min.

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## APPENDIX A

### Other Publications From This Study

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Rice, V.J. and M. Sharp. Prediction of performance on two stretcher-carry tasks. Work: J Prevention, Assessment, and Rehabilitation, 4(3): 201-210, 1994.

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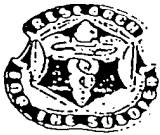
Rice, V.J.B., M. Sharp, W.J., and T.L. Williamson. The effects of gender, team size, and a shoulder harness on a stretcher-carry task and post-carry performance, Part II: A mass casualty simulation. Int J Industrial Ergonomics, 18: 41-49, 1996.

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Tharion, W.J., V.J. Rice, M.A. Sharp, and B.E. Marlowe. The effects of litter carrying on rifle shooting. Milit Med, 158(8): 566-570, 1993.



# APPENDIX B. SORENESS, PAIN AND DISCOMFORT QUESTIONNAIRE

INSTRUCTIONS: Rate the degree of soreness, pain or discomfort that you are currently feeling for body parts 1 - 11. Do so for the front and the back of the body.

NAME: \_\_\_\_\_

DATE: \_\_\_\_\_

PLEASE CIRCLE

Harness      No Harness  
2 man        4 man  
pretest      post test  
15 min carry   prolonged carry

15 min.  
4 0=N 2 man 1=pre  
4 1=H 4 man 2=post

Prolonged  
4 5=N 2 man 1=pre  
4 6=N 4 man 2=post

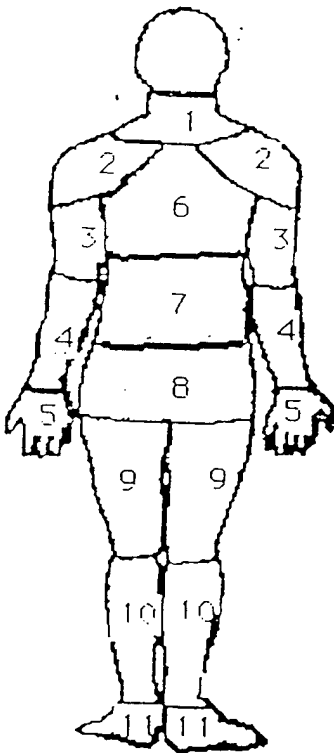
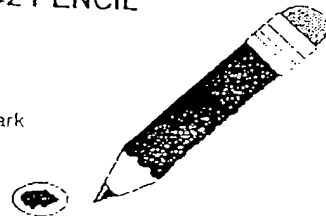
CARRY

SUBJ #

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| 0 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 1 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 2 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 3 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 4 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 5 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 6 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 7 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 8 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 9 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

PLEASE USE A #2 PENCIL

Proper Mark



FRONT OF BODY

NONE  
VERY SLIGHT  
MILD  
MODERATE  
SEVERE  
EXTREME

|                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1                     | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     | 8                     | 9                     | 10                    | 11                    |
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BACK OF BODY

NONE  
VERY SLIGHT  
MILD  
MODERATE  
SEVERE  
EXTREME

|                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1                     | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     | 8                     | 9                     | 10                    | 11                    |
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